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Results of exploratory drilling for lignite in 1978, Fort Peck Indian Reservation, Roosevelt County, Montana

By

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards.

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Results of exploratory drilling for lignite in 1978, Fort Peck Indian Reservation, Roosevelt County, Montana

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Introduction

Twelve exploratory holes and eight core holes were drilled for lignite in the Fort Peck Indian Reservation during October and November 1978. The drilling was done as part of the U.S. Geological Survey's program to assess the coal resources in the Reservation. This preliminary report makes available the logs of the exploratory holes and the analyses of coal samples obtained from the core holes. Geologic interpretations resulting from this and other investigations on the Reservation are not published here.

The Fort Peck Indian Reservation has been previously mapped by several investigators. Outcropping lignite beds in the Reservation were described and located by Smith (1910). Colton and Bateman (1956) prepared a generalized geologic and structure contour map of the Fort Peck Indian Reservation. Witkind (1959) and others mapped and summarized the Quaternary geology of the southeastern part of the reservation; Colton (1963) mapped the southwestern part of the area covered in this report; and the Great Northern Railway Company (1966, now Burlington Northern, Inc.) investigated the Fort Kipp lignite deposit. Principal objectives of the investigations described in this report include a comprehensive study and the assessment of coal resources in the eastern part of the Fort Peck Indian Reservation, by integration and synthesis of preexisting information with new field studies and drilling information.

Funding for these investigations was provided by the U.S. Bureau of Indian Affairs. The investigations have proceeded with the authorization and cooperation of the Fort Peck Tribal Executive Board, Norman Hollow, Executive Chairman. Carl Fourstar, Director, Fort Peck Tribal Research Program, and Frances Eagleman, Realty Officer, U.S. Bureau of Indian Affairs, provided liaison with the U.S. Geological Survey and were most helpful in expediting the work.

The drilling described here was done by Mountain States Drilling Company, Denver, Colo., under contract to the U.S. Geological Survey. Geophysical logs of the drill holes were made by Roberts Geophysical Services, Council Bluffs, Iowa, also under contract to the U.S. Geological Survey. Assistance in these investigations was provided by the following U.S. Geological Survey personnel: Ronald H. Affolter aided materially in preparing the data tables; Betty L. Arnone drafted several of the illustrations; Thomas M. Kehn monitored some of the drilling; Casey L. Lepp assisted in the study and description of drill cuttings; Carolyn L. Thompson and Janet L. Brown assisted in the siting of drill holes; and Roger B. Colton provided unpublished geologic data.

Location

The Fort Peck Indian Reservation occupies about 3,000 square miles in Daniels, Roosevelt, Sheridan, and Valley Counties, northeastern Montana (fig. 1). The Missouri River, a major feature in the area, forms the south boundary of the reservation. The reservation extends eastward from Porcupine Creek to Big Muddy Creek. The north boundary is roughly parallel to lat 48°31′ N. (fig. 2). The reservation is in the Northern Great Plains province and is comprised of rolling uplands that are dissected by the Missouri and Poplar Rivers and their tributaries. Principal towns on the reservation are located along the southern margin on U.S. Highway 2 and along the mainline of the Burlington-Northern Railroad.

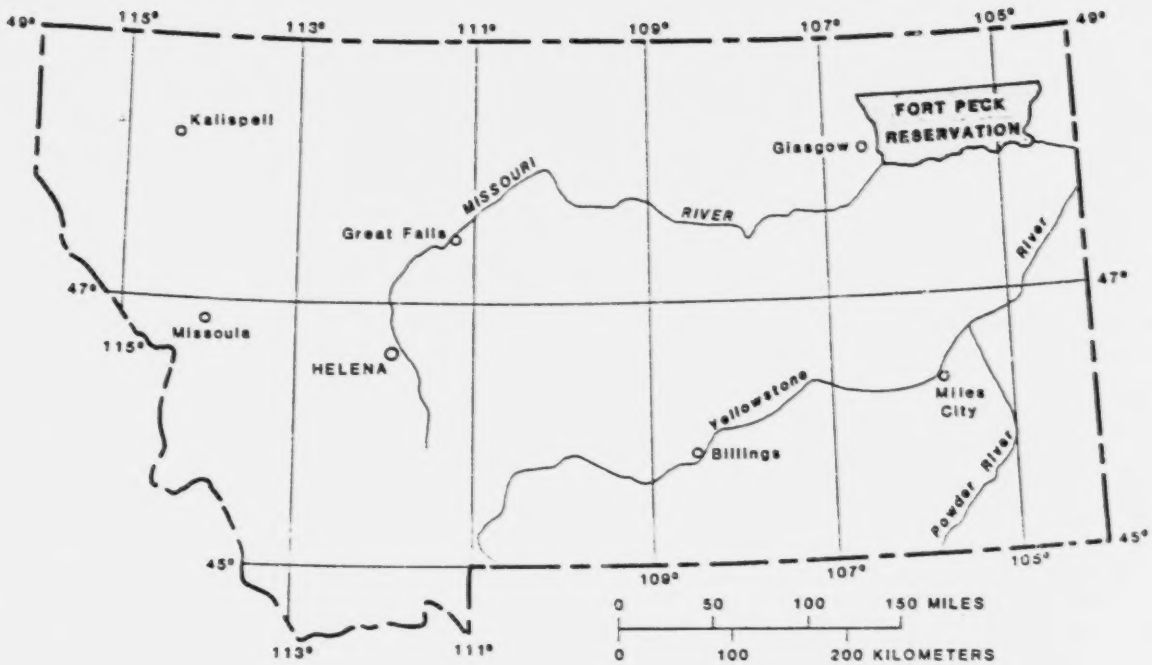

Figure 1.--Index map of Montana showing location of Fort Peck Indian Reservation.

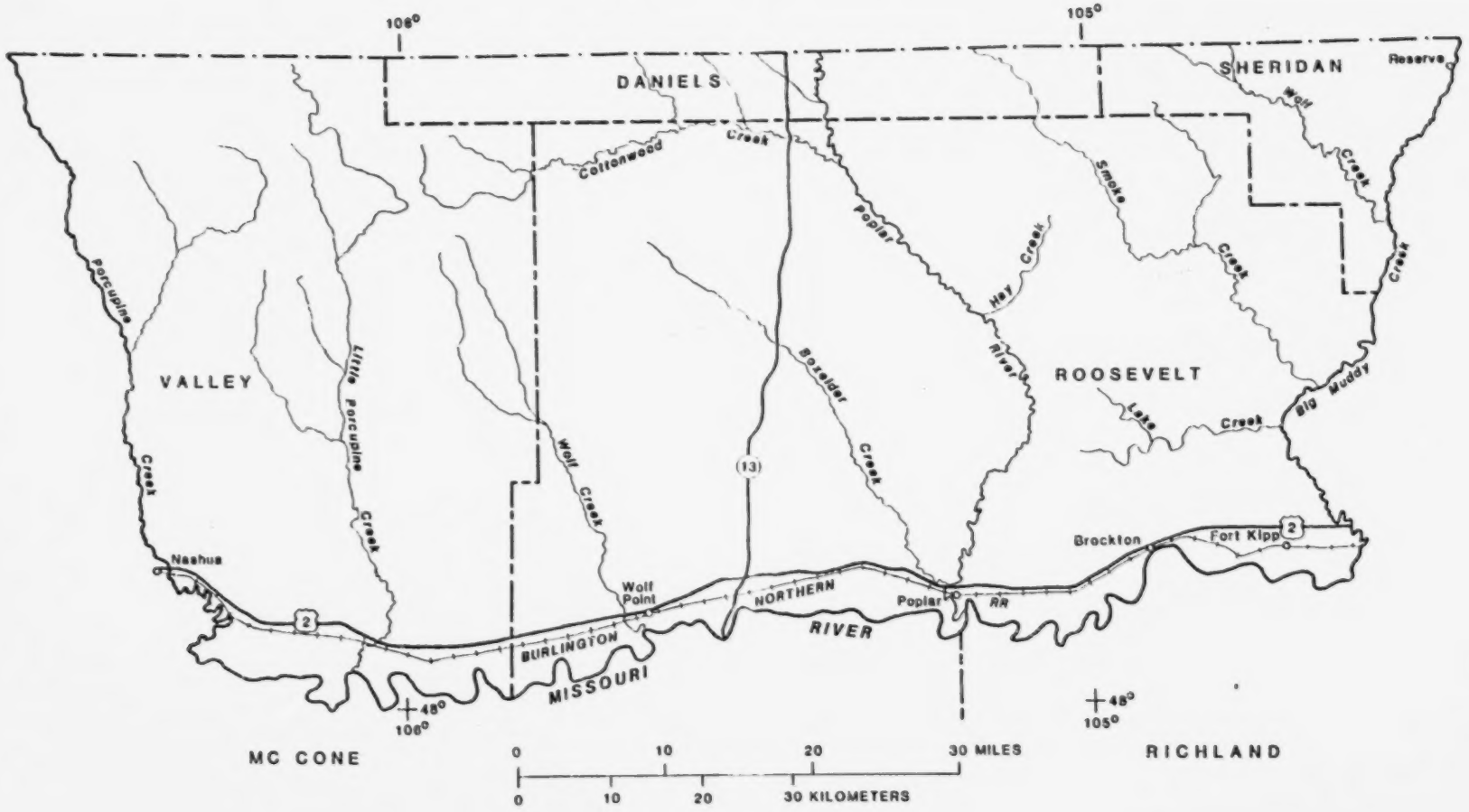

Figure 2.--Index map of Fort Peck Indian Reservation, northeastern Montana.

Most of the coal-bearing rocks underlying the reservation, the focus of these investigations, lie between the Poplar River and Big Muddy Creek and are included in the Fort Peck Indian Reservation lignite field of Smith (1910). The drilling described in this report tested only those coal-bearing rocks underlying the southeastern part of the Fort Peck Indian Reservation.

Geologic setting

Coal-bearing rocks in the Fort Peck Indian Reservation are in the Hell Creek Formation of Late Cretaceous age and the Fort Union Formation of Paleocene age. Much of the coal-bearing sequence is buried under Pleistocene glacial deposits. Bedrock is exposed along some roadcuts and commonly along streambeds, however, extensive continuous rock exposures are rare and it is necessary to resort to exploratory drilling at many localities in order to obtain information on the coal-bearing sequence.

The Hell Creek Formation is mainly soft shale and siltstone interbedded with ledge-forming sandstone, and also includes fairly numerous but relatively thin and discontinuous beds of lignite. The formation is as much as 280 feet thick in the vicinity of the Fort Peck Indian Reservation. Somber gray claystone and siltstone predominate in the middle and upper parts of the formation, and brown sandstone dominates the lower part. Coals in the formation rarely exceed 3 feet in thickness; consequently, the formation is of little or no economic importance in the vicinity of the reservation.

The Fort Union Formation conformably overlies the Hell Creek Formation. The contact between these formations is gradational and is arbritrarily placed at the base of the lowest mappable lignite bed (Colton and Bateman, 1956). Somber gray beds of the Hell Creek generally prevail below this horizon in subtle contrast with the overlying brighter yellow-hued beds comprising the Fort Union.

The Fort Union Formation is about 1,000 feet thick in the southeastern part of the Fort Peck Indian Reservation where it consists mainly of claystone, siltstone, and sandstone, and includes nine beds of lignite ranging from 2 to 10 feet in thickness, and numerous beds of lignite less than 2 feet thick. Although the formation underlies most of the reservation east of the Poplar River, erosion has removed all but the lower few hundred feet of the formation in the vicinity of the Poplar River. The formation dips gently eastward in the area of these investigations, and the thickest sequence of strata assigned to the Fort Union underlies the eastern part of the reservation. The Fort Union Formation is known to contain potentially recoverable lignitic coal at several places in the eastern part of the reservation; however, the relationship of these known coal deposits to each other and to other recoverable deposits that may be present is little understood.

Coal exploratory drill holes

Twelve exploratory holes and eight core holes were drilled in the southeastern part of the Fort Peck Indian Reservation in 1978 in order to obtain information on the quality, quantity and distribution of coal beds in the Fort Union Formation. The locations of the drill holes and the area in the southeastern part of the reservation underlain by the coal-bearing Fort Union Formation is shown in figure 3. The stratigraphic intervals of the Fort Union Formation tested by this drilling is shown in figure 4.

All drilling was done with a medium-range truck-mounted rotary drill. Water and mud additives were used as a drilling medium. Samples of drill cuttings were collected at 5-foot intervals and were described in the field and later studied under a microscope in the office.

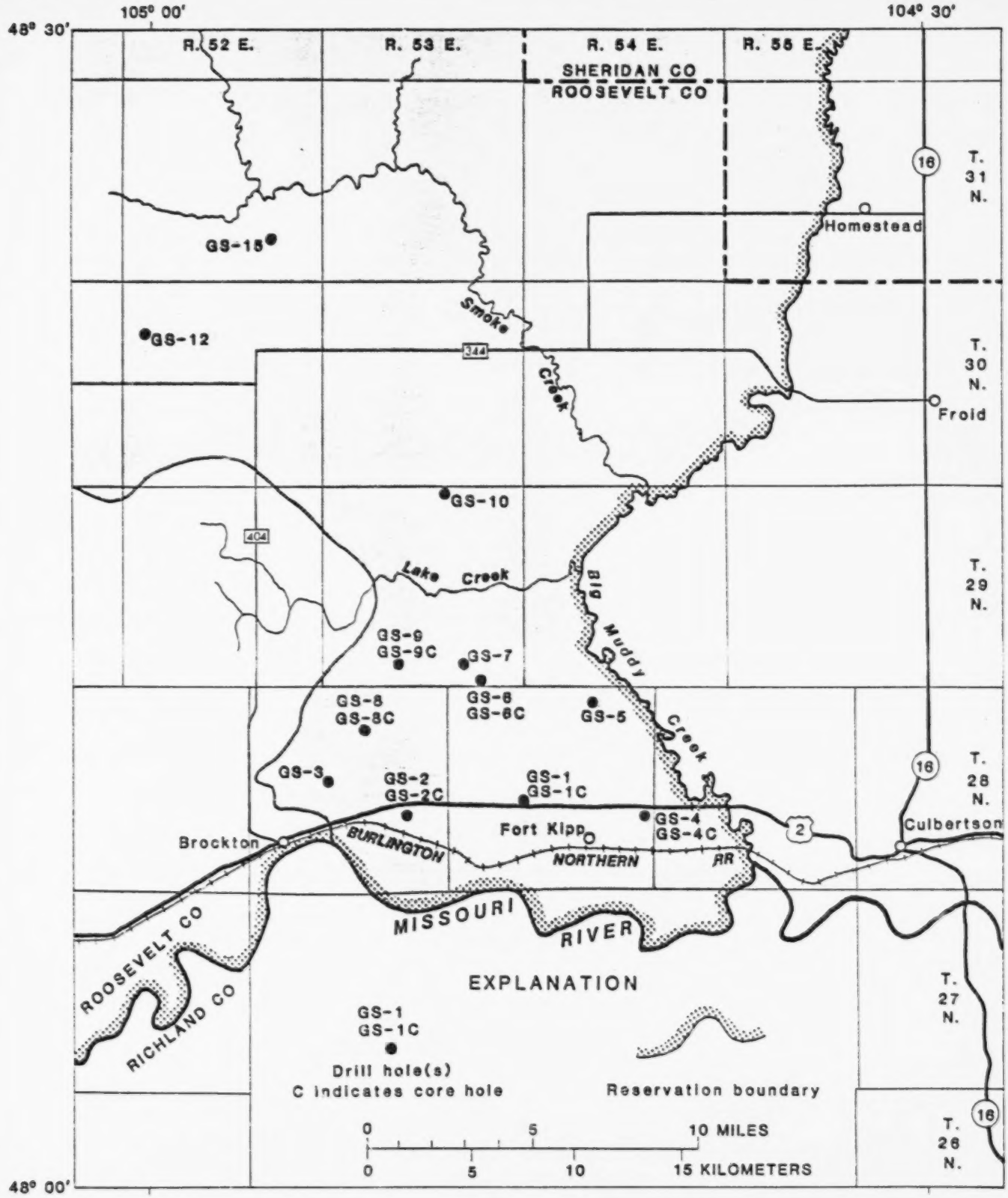

Figure 3.--Map showing locations of drill holes and area underlain by Fort Union Formation (shaded), southeastern part of the Fort Peck Indian Reservation, Montana.

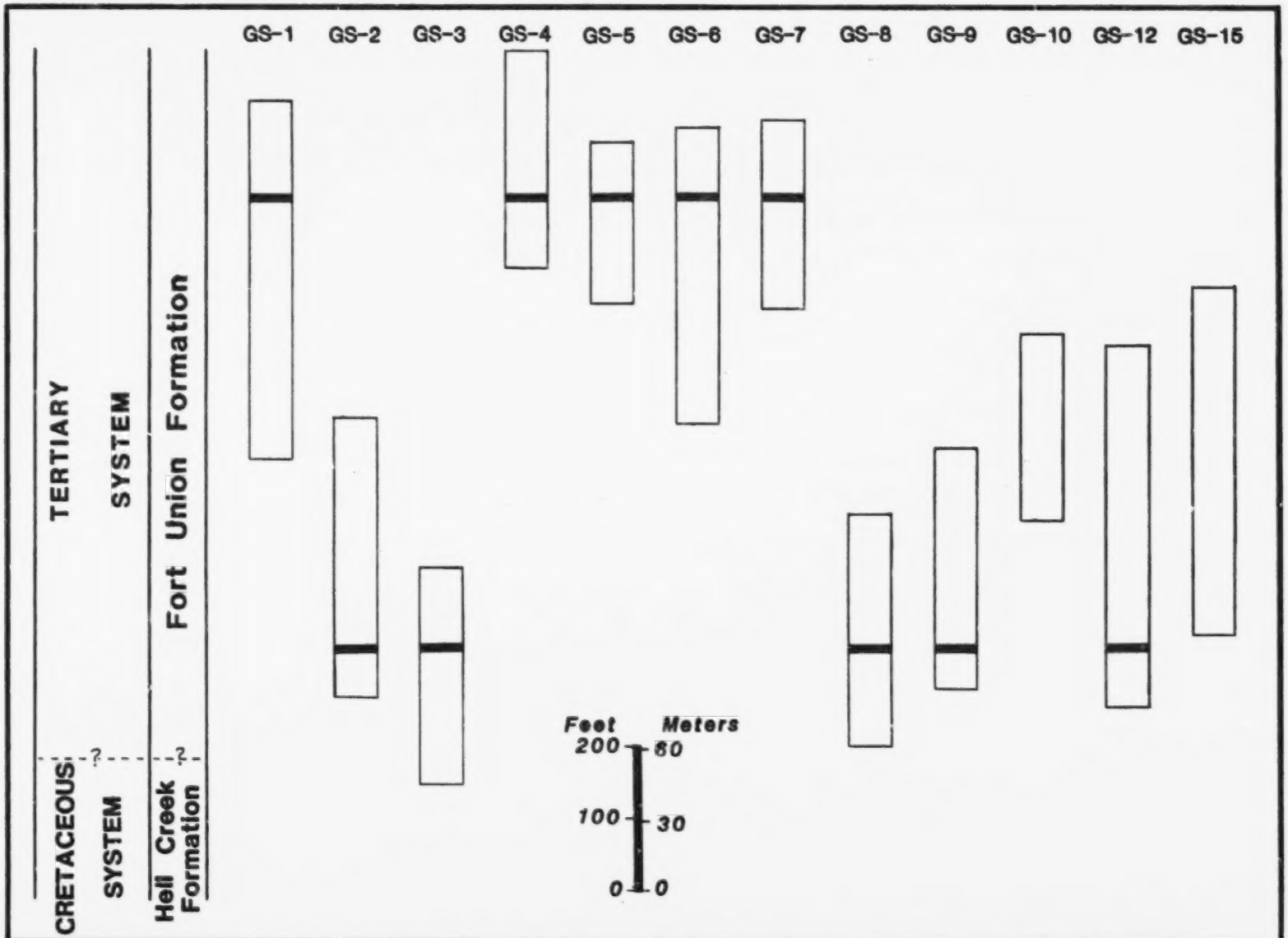

Figure 4.--Diagram showing stratigraphic intervals of Fort Union and Hell Creek Formations penetrated by drill holes GS-1 through GS-10, GS-12, and GS-15 with dark bands signifying coal.

Core holes were located within a few feet of six of the 1978 exploratory drill holes (fig. 3). Selected intervals were cored to obtain fresh samples of coal for analysis. Cored intervals are indicated on the accompanying geophysical logs, and descriptions of the cores and samples taken are included with the sample and geophysical logs.

Logs of the drill holes

Sample logs of coal exploratory holes described in this report were prepared by examining drill cutting samples under a microscope to determine the lithology of the strata tested and utilizing the geophysical logs to ascertain tops and bottoms of stratigraphic units discerned from examination of the drill cuttings.

Geophysical logs of the exploratory holes were made with a single conductor logging tool. A natural-gamma log was run going into the hole and a single-point resistance log was made on the trip out of the hole. Density (gamma-gamma) and caliper logs were made on subsequent runs, each of the last two logs requiring a separate run in and out of the hole. Focused density (high resolution) logs were made at an expanded scale (1 inch = 5 feet) of selected coal zones at several sites. It was not possible to make all five logs noted here at some sites because of logging equipment failures or caving and blockage of holes. Only the natural gamma and density logs are reproduced in this report.

Conversion to metric units

Units of measurement used in this report are in the English system. Factors for conversion to the metric system are:

English system	Metric system
1 foot	0.3048 meter
1 mile	1.609 kilometers
1 square mile	2.509 square kilometers
1 British thermal unit/pound	0.5556 kilogram-calories/kilogram

Sample log

Hole no.: GS-1 Date: 10-19-78 State: Montana County: Roosevelt
Elev. (ground): 2225 ft Location: T. 28 N., R. 54 E., Sec. NW NW 21
Total depth: 500 ft Drilling medium: mud Offset core hole: GS-1C

Depth (feet)	Description
0-10	Sand, silt, and clay, greenish-gray, unconsolidated
10-15	Claystone, light-gray
15-20	Siltstone, yellowish-gray, calcareous, argillaceous
20-26	Claystone, light-gray to yellowish-gray, calcareous
26-43	Siltstone, light-gray and grayish-orange-pink, calcareous
43-58	Claystone, dark-greenish-gray to light-gray, calcareous; carbonaceous claystone and coal laminations in upper part
58-73	Siltstone, light-olive-gray to grayish-orange, calcareous; thin carbonaceous claystone and coal laminations in upper part; grades to silty claystone between 63 and 68 ft
73-79	Claystone, light-gray to grayish-orange, calcareous
79-85	Siltstone, light-gray to grayish-orange, calcareous; slightly sandy in upper part; grades to claystone near base
85-107	Claystone, light-gray to grayish-yellow, silty, calcareous
107-112	Siltstone, medium-light-gray
112-117.2	Claystone, light-olive-gray, silty
117.2-126	Lignite, black; claystone parting from 124.8 and 125 ft; see core sample D209957 (fig. 6)
126-134.7	Claystone, light-olive-gray, calcareous; scattered thin carbonaceous laminations
134.7-143.7	Lignite, black; abundant thin carbonaceous shale laminations in in middle to upper part; see core sample D209958 (fig. 6)
143.7-163	Claystone, medium-light-gray, silty, calcareous; interbedded with siltstone between 150 and 155 ft
163-175	Siltstone, greenish-gray to light-gray, calcareous
175-176	Lignite, black
176-190	Claystone, light-gray, calcareous; grades to siltstone near base

Sample log--Continued

Depth (feet)	Description
190-198	Siltstone, light-gray
198-206	Claystone, brownish-gray, carbonaceous; includes thin coal
206-228	Siltstone and silty claystone, light-gray to olive-gray; calcareous in upper part; includes scattered thin beds of carbonaceous shale and impure coal
228-229.8	Lignite, black
229.8-235	Claystone, medium-light-gray to greenish-gray
235-253	Siltstone, medium-light-gray and yellowish-orange, locally sandy; scattered thin beds of coal and carbonaceous shale
253-260	Claystone, medium-dark- to dark-gray, calcareous
260-276	Siltstone and silty claystone, medium-light-gray and yellowish-orange, calcareous
276-333	Siltstone and silty sandstone, light-gray, calcareous; scattered thin beds of carbonaceous shale and coal
333-348	Claystone, light-gray to olive-gray, silty, calcareous; scattered thin beds of carbonaceous shale and coal
348-370	Siltstone and silty claystone, light-olive-gray, calcareous
370-372	Limestone concretion, brownish-gray to olive-gray, hard, dense
372-398	Claystone, brownish-gray to greenish-gray, calcareous; very silty in middle and lower parts
398-409	Siltstone, greenish-gray to light-olive-gray; grades locally to sandstone; includes some interbedded silty claystone and scattered limestone concretions
409-410	Lignite
410-475	Siltstone, greenish-gray to brownish-gray, locally sandy, calcareous; includes interbedded brownish-gray silty claystone which is fairly abundant in middle to lower parts of interval; scattered limestone concretions
475-476	Lignite, impure
476-481	Claystone, brownish-gray, carbonaceous
481-482	Lignite, impure
482-500	Siltstone and claystone, brownish-gray to greenish gray; traces of carbonaceous shale and coal; scattered limestone concretions
	Total depth 500 ft

Hole no.: GS-1 Date: 10/19/78 State: Montana County: Roosevelt

Elev. (ground); 2225 ft Location: T. 28 N., R. 54 E., Sec. NW NW 21

Total depth: 500 ft Bit size: 5.5 in Logging speed: 15 ft/min

Natural gamma: Time constant 4 Count range 50 cps

Density (gamma-gamma ray): Time constant 4 Count range 1,000 cps

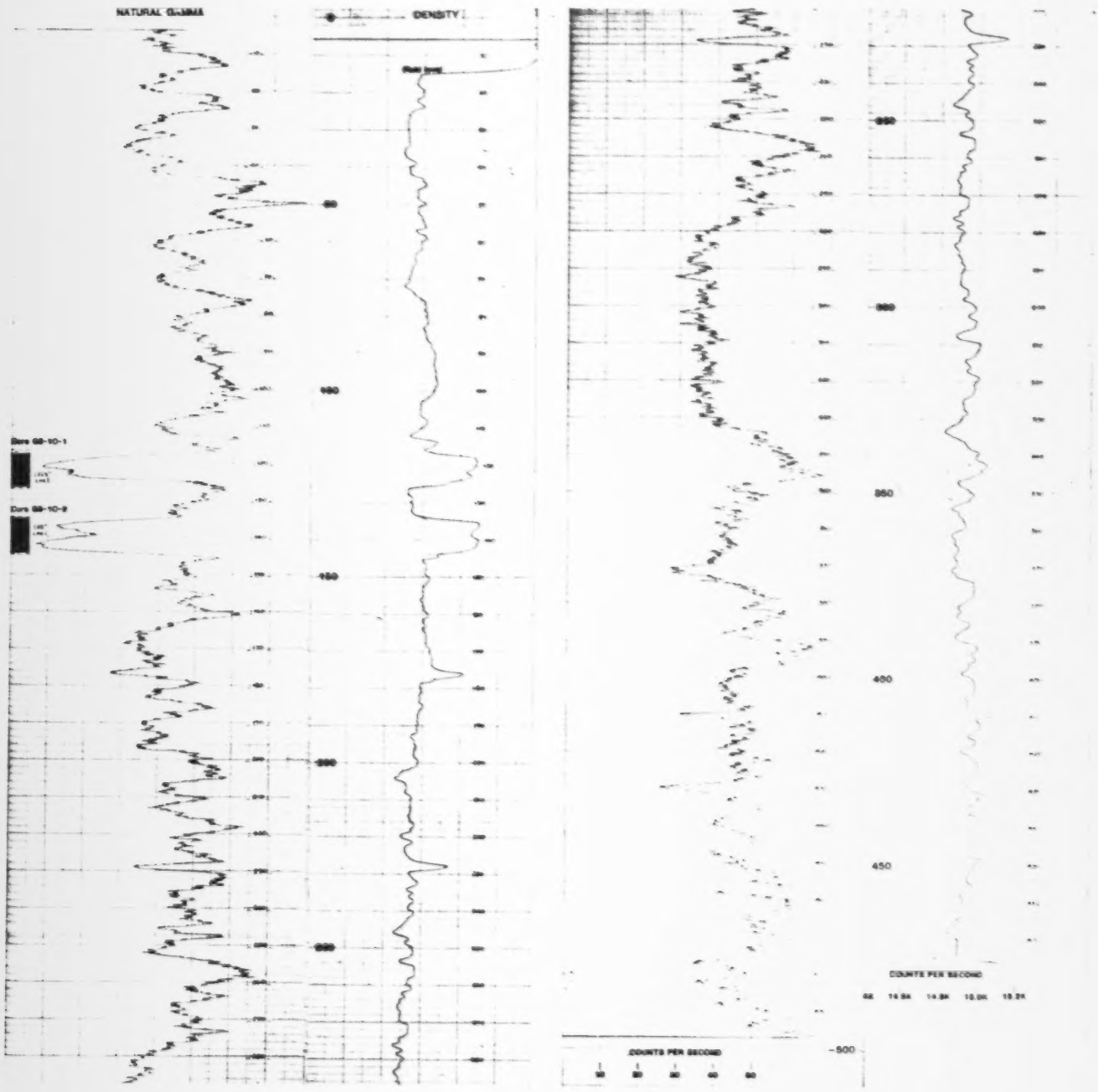

Figure 5.--Geophysical logs of hole GS-1.

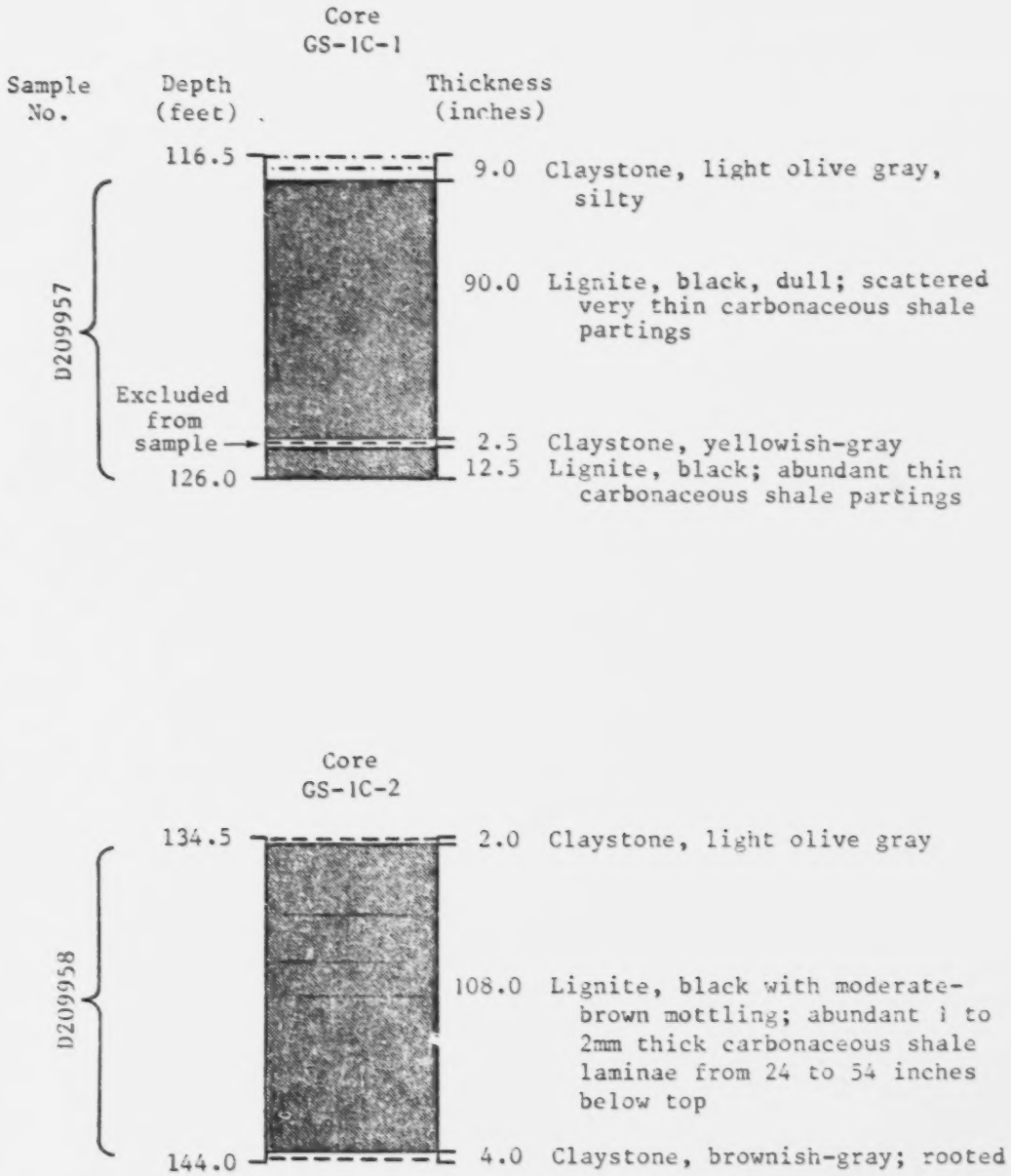

Figure 6.--Core and sample descriptions, core hole GS-1C, NW NW sec. 21, T. 28 N., R. 54 E., Roosevelt County, Montana.

Sample log

Hole no.: GS-2 Date: 10-10-78 State: Montana County: Roosevelt

Elev. (ground): 2125 ft Location: T. 28 N., R. 53 E., Sec. NW SE 23

Total depth: 380 ft Drilling medium: mud Offset core hole: GS-2C & GS-2C'

Depth (feet)	Description
0-20	Gravel, sand, and clay, yellowish-brown, unconsolidated
20-26	Claystone, grayish-orange-pink, calcareous; includes thin limonitic laminations
26-28	Lignite, black
28-29	Carbonaceous shale
29-32	Lignite, black
32-52	Claystone, greenish-gray and grayish-orange, very silty, some iron-stained; includes carbonaceous shale between 38 and 42 ft
52-74	Siltstone, yellowish- to greenish-gray, calcareous; includes greenish-gray claystone between 61 and 65 ft
74-83	Claystone, light- to dark-greenish-gray; grades silty in middle of unit
83-84.2	Lignite, slightly impure
84.2-104	Siltstone, light-gray, sandy; grades to claystone in upper and lower parts
104-107	Carbonaceous shale and impure coal
107-156	Siltstone, greenish-gray, sandy, calcareous; grades to silty sandstone at base
156-159	Claystone, light-olive-gray, silty; includes thin streaks of coal
159-160	Lignite, impure
160-161	Carbonaceous shale
161-164.8	Lignite, black; grades impure in upper part
164.8-170	Claystone, brownish-gray to light-olive-gray
170-204	Siltstone, greenish-gray to light-olive-gray, sandy, calcareous; includes limestone concretion at 199 ft
204-222	Claystone, light-olive-gray, silty, locally carbonaceous

Sample log--Continued

Depth (feet)	Description
222-236	Siltstone, light-gray to light-olive-gray, calcareous; contains scattered limestone concretions; grades to sandstone at base
236-239	Claystone, light-olive-gray
239-240.5	Lignite, black
240.5-243.7	Siltstone, medium-gray, slightly sandy
243.7-248.8	Lignite, black, grades impure in upper part; see core samples numbered D-209953 and D-209954 (fig. 8)
248.8-254	Claystone, light-olive-gray; grades silty in lower part
254-286	Siltstone, light-gray to dark-greenish-gray, sandy, calcareous
286-290	Claystone, greenish-gray
290-294.5	Lignite, black; see core sample D-209955 (fig. 8)
294.5-304.4	Claystone, light-olive-gray to brownish-gray; includes scattered carbonaceous laminations
304.4-311.9	Lignite, black with moderate-brown mottling; grades impure in upper 5 inches; see core sample D-209956 (fig. 8)
311.9-328	Claystone and siltstone, light-gray to greenish-gray; claystone predominates
328-350	Siltstone, light-gray to greenish gray, sandy, slightly calcareous; grades to claystone in middle of
350-367	Claystone, light-gray to greenish-gray, silty in lower part
367-380	Siltstone, light-gray to greenish-gray, sandy; geophysical logs indicate thin coal at 368 ft
	Total depth 380 ft

Hole no.. GS-2 Date: 10/10/78 State: Montana County: Roosevelt
Elev. (ground): 2125 ft Location: T. 28 N., R. 53 E., Sec. NW SE 23
Total depth: 380 ft Bit size: 4.75 in Logging speed: 15 ft/min
Natural gamma: Time constant 4 Count range 50 cps
Density (gamma-gamma ray): Time constant 4 Count range 2,500 cps

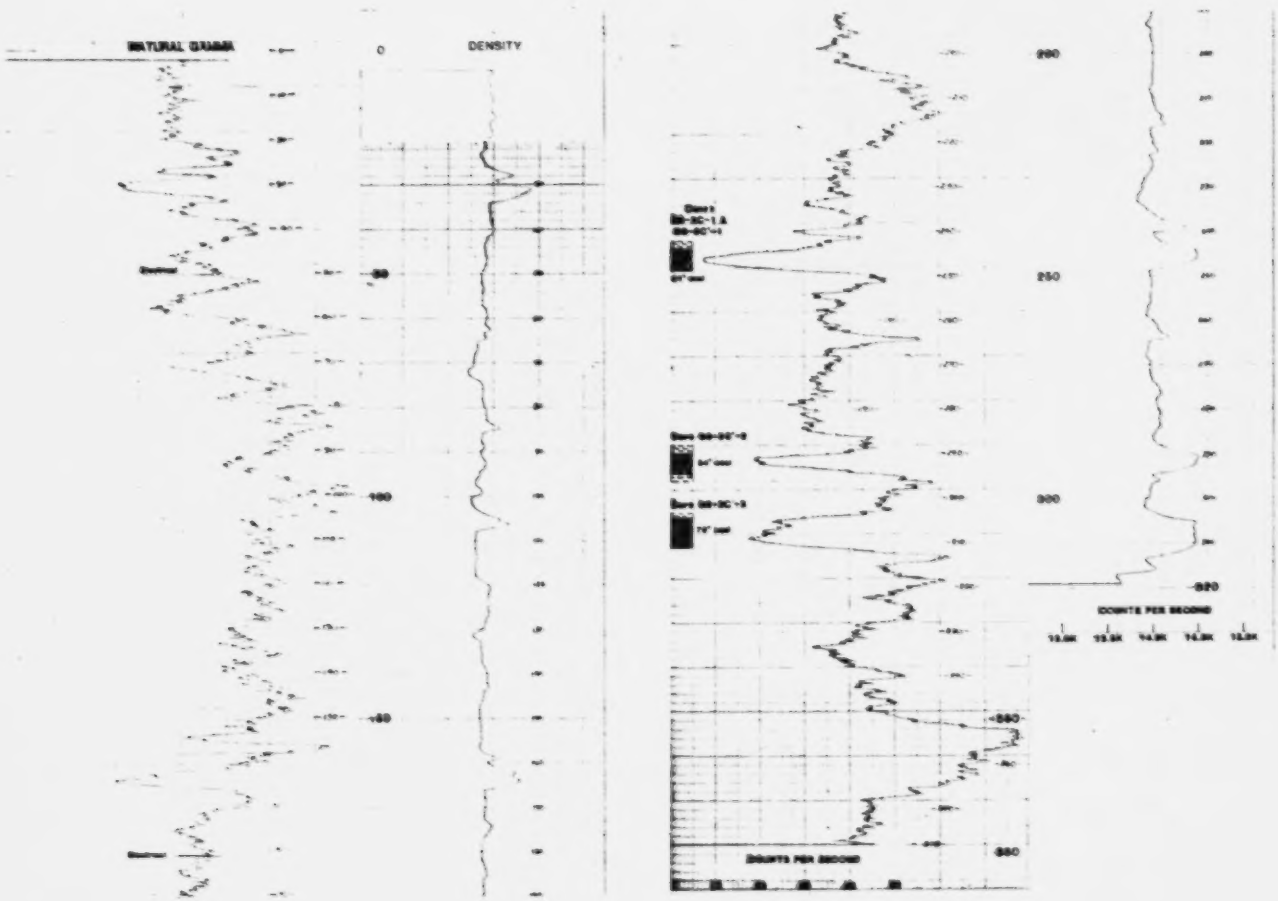

Figure 7.--Geophysical logs of hole GS-2.

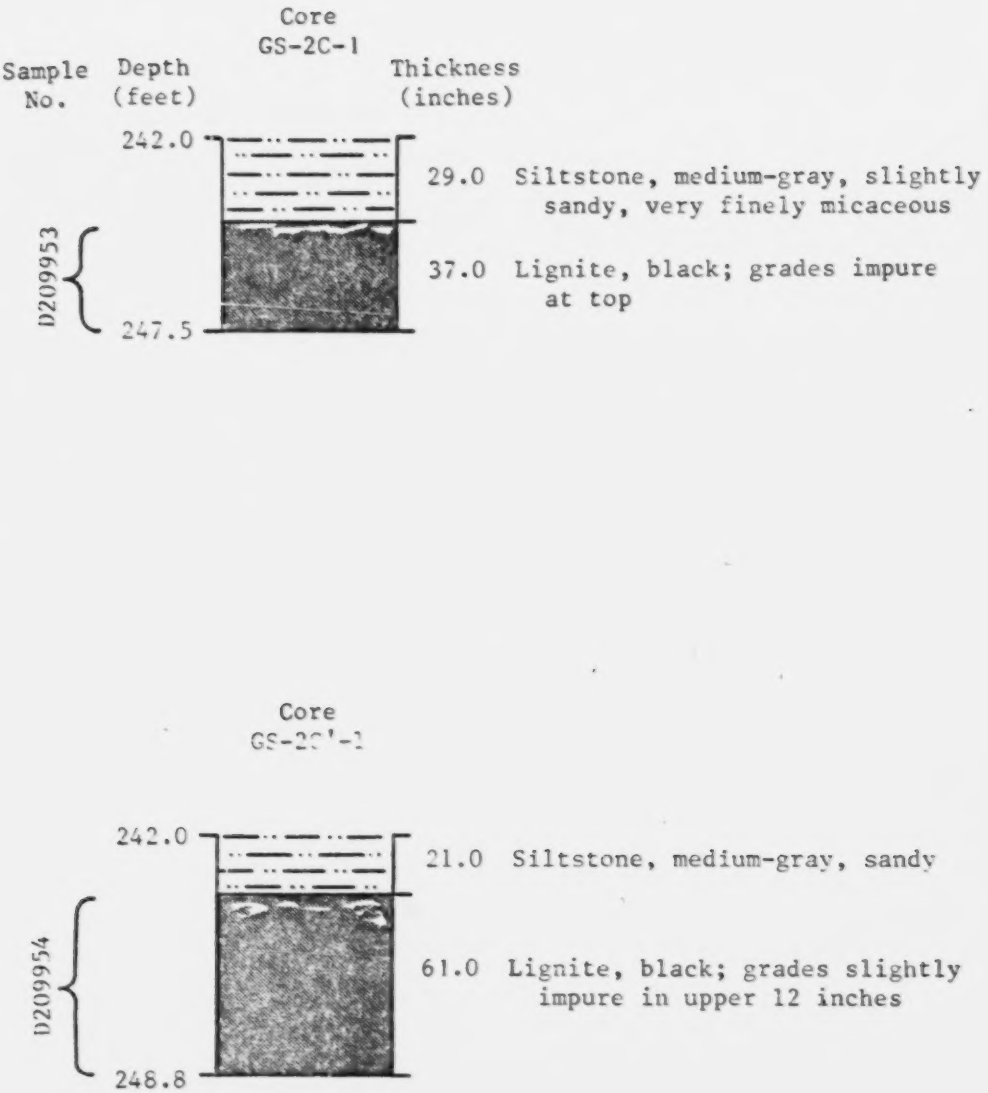

Figure 8.--Core and sample descriptions, core holes GS-2C and GS-2C', NW SE sec. 23, T. 28 N., R. 53 E., Roosevelt County, Montana.

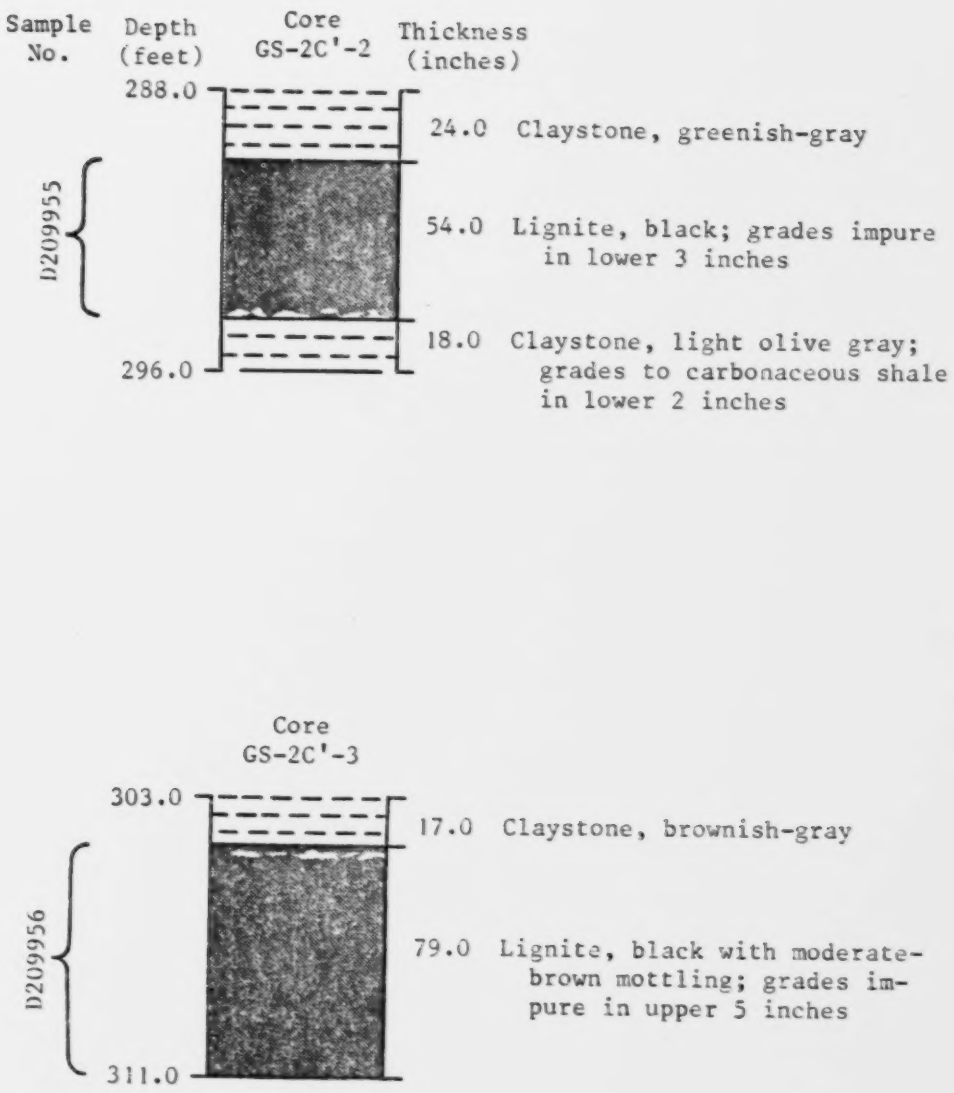

Figure 9.--Core and sample descriptions, core hole GS-2C', NW SE sec. 23, T. 28 N., R. 53 E., Roosevelt County, Montana.

Sample log

Hole no.: GS-3 Date: 10-14-78 State: Montana County: Roosevelt
Elev. (ground): 2203 ft Location: T. 28 N., R. 53 E., Sec. SW SW 16
Total depth: 300 ft Drilling medium: mud Offset core hole: none

Depth (feet)	Description
0-10	Sand and gravel
10-106	Clay, sand, and gravel; detrital coal fragments between 30 and 40 ft
106-114	Lignite, black
114-128	Claystone, light-gray to greenish-gray, silty
128-136	Siltstone, light-gray, slightly calcareous, sandy
136-163	Claystone, light-gray to dark-greenish-gray and grayish-orange, silty; grades to sandy siltstone at base
163-172	Claystone, greenish-gray to dark-greenish-gray; grades to sandy siltstone between 165 and 168 ft
172-181	Siltstone, greenish-gray; includes some interbedded claystone in upper part
181-182.5	Lignite, black
182.5-196.5	Claystone, greenish-gray to dark-greenish-gray; includes thin beds of carbonaceous shale and coal between 188 and 192 ft
196.5-198	Lignite, black
198-207	Siltstone, dark-greenish-gray
207-213	Claystone, light-gray to greenish-gray, calcareous
213-217	Lignite, black; grades impure in upper part
217-240	Claystone, dark-greenish-gray; grades silty at base
240-252	Siltstone, medium-gray to greenish-gray, sandy, slightly calcareous; geophysical logs indicate thin impure coal at base of interval
252-268	Claystone, dark-greenish-gray, silty
268-300	Siltstone, greenish-gray, sandy
	Total depth 300 ft

Hole no.: GS-3 Date: 10/15/78 State: Montana County: Roosevelt
Elev. (ground): 2203 ft Location: T. 28 N., R. 53 E., Sec. SW 16
Total depth: 300 ft Bit size: 5½ in Logging speed: 15 ft/min
Natural gamma: Time constant 4 Count range 50 cps
Density (gamma-gamma ray): Time constant 4 Count range 1,000 cps

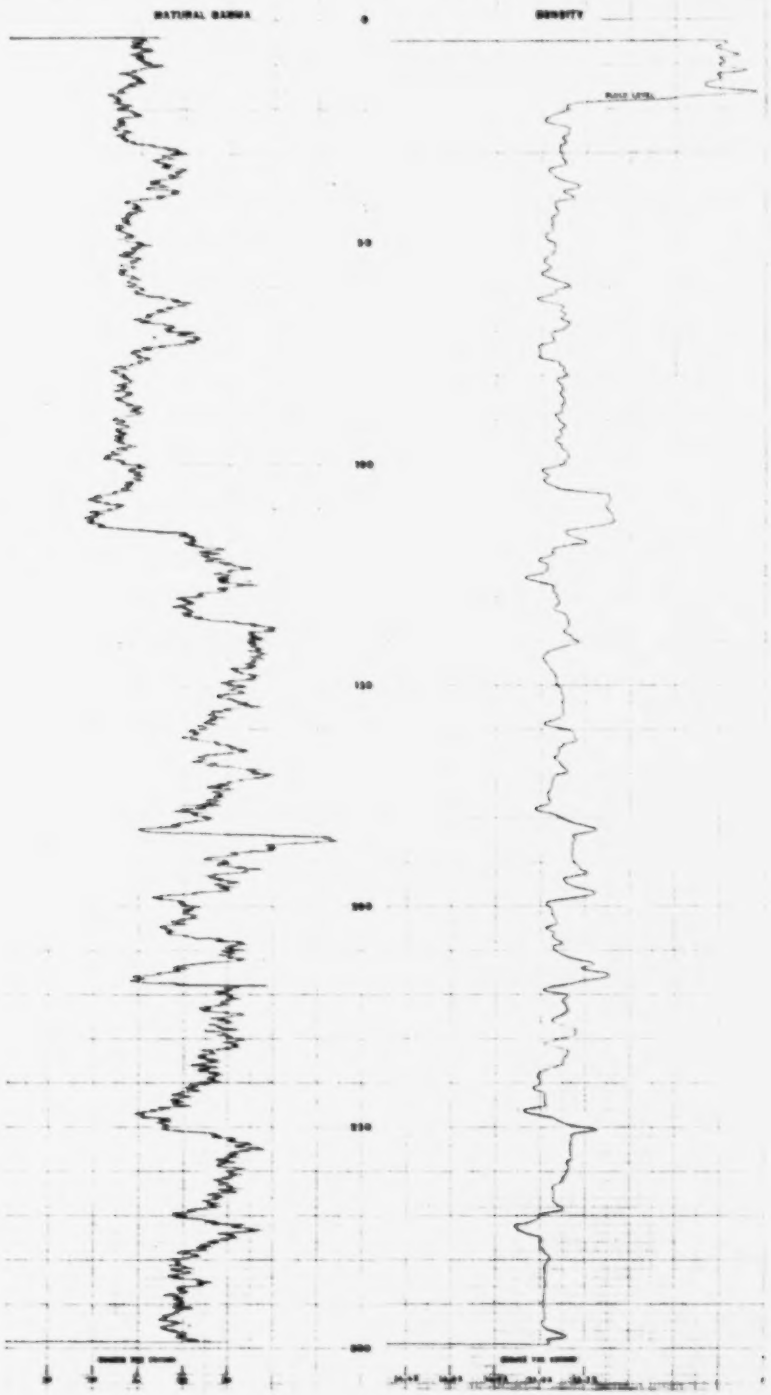

Figure 10.--Geophysical logs of hole GS-3.

Sample log

Hole no.: GS-4 Date: 10-20-78 State: Montana County: Roosevelt
Elev. (ground): 2090 ft Location: T. 28 N., R. 54 E., Sec. NE SE 24
Total depth: 300 ft Drilling medium: mud Offset core hole: GS-4C

Depth (feet)	Description
0-22	Gravel, sand, silt, and clay, yellowish-gray, unconsolidated
22-28	Sandstone, yellowish-gray, very fine grained, micaceous; traces of gypsum, magnetite, and pyrite
28-34	Claystone and siltstone, yellowish-gray to light-olive-gray
34-47	Sandstone, dusky-yellow, very fine grained, micaceous, calcareous; traces of magnetite and pyrite
47-52	Carbonaceous shale and impure coal, grayish-black to brownish-black
52-60	Sandstone, light-olive-gray to light-gray, very fine grained, silty, calcareous; trace amounts of pyrite, magnetite, and gypsum
60-86	Siltstone and claystone, medium-gray to greenish-gray; siltstone predominates in upper and lower parts of interval; thin, impure coal at 76 ft
86-88	Limestone concretion, brownish-gray to olive-gray, hard
88-119	Sandstone, light- to medium-gray, very fine grained, silty, calcareous; scattered thin limestone concretions; trace amounts of magnetite, gypsum, muscovite, and chlorite (?)
119-121	Limestone concretion
121-150	Claystone and siltstone, medium-light-gray to greenish-gray, locally sandy, calcareous
150-152.4	Claystone, light-olive-gray, silty
152.4-156.2	Lignite, black; grades slightly impure at top; includes claystone parting between 154.5 and 154.7 ft; see core samples D209959 and D209960 (fig. 12)
156.2-162	Claystone, light-olive-gray, silty
162-168	Siltstone, medium-light-gray, sandy, calcareous; includes thin limestone concretion
168-175	Claystone, medium-light-gray to brownish-gray, calcareous
175-181	Sandstone, light- to medium-light-gray, silty, calcareous

Sample log--Continued

Depth (feet)	Description
181-188	Claystone, light-gray to light-olive-gray, calcareous
188-202.1	Sandstone, medium-light-gray, very fine grained, silty, calcareous
202.1-210.1	Lignite, black with moderate-brown mottling; includes abundant carbonaceous shale laminae in upper part; grades slightly impure at base; see core sample D209961 (fig. 12)
210.1-215	Claystone, greenish-gray, silty
215-236	Sandstone, light- to medium-gray, silty, calcareous; includes brownish-gray claystone between 223 and 227 ft
236-238	Claystone, brownish-gray to light-olive-gray
238-241	Lignite, black
241-245	Claystone, brownish-gray, carbonaceous
245-290	Sandstone, siltstone, and claystone, medium-light-gray to brownish-gray, calcareous; 5 to 8 ft thick units of silty sandstone separated by 3 to 5 ft thick units of silty claystone and siltstone; thin coal at 260 ft; limestone concretions in basal 5 ft
290-300	Siltstone, light- to medium-gray, sandy, calcareous
	Total depth 300 ft

Hole no.: GS-4 Date: 10/21/78 State: Montana County: Roosevelt
Elev. (ground): 2090 ft Location: T. 28 N., R. 54 E., Sec. NE SE 24
Total depth: 300 ft Bit size: 5.5 in Logging speed: 15 ft/min
Natural gamma: Time constant 4 Count range 50 cps
Density (gamma-gamma ray): Time constant 4 Count range 1,000 cps

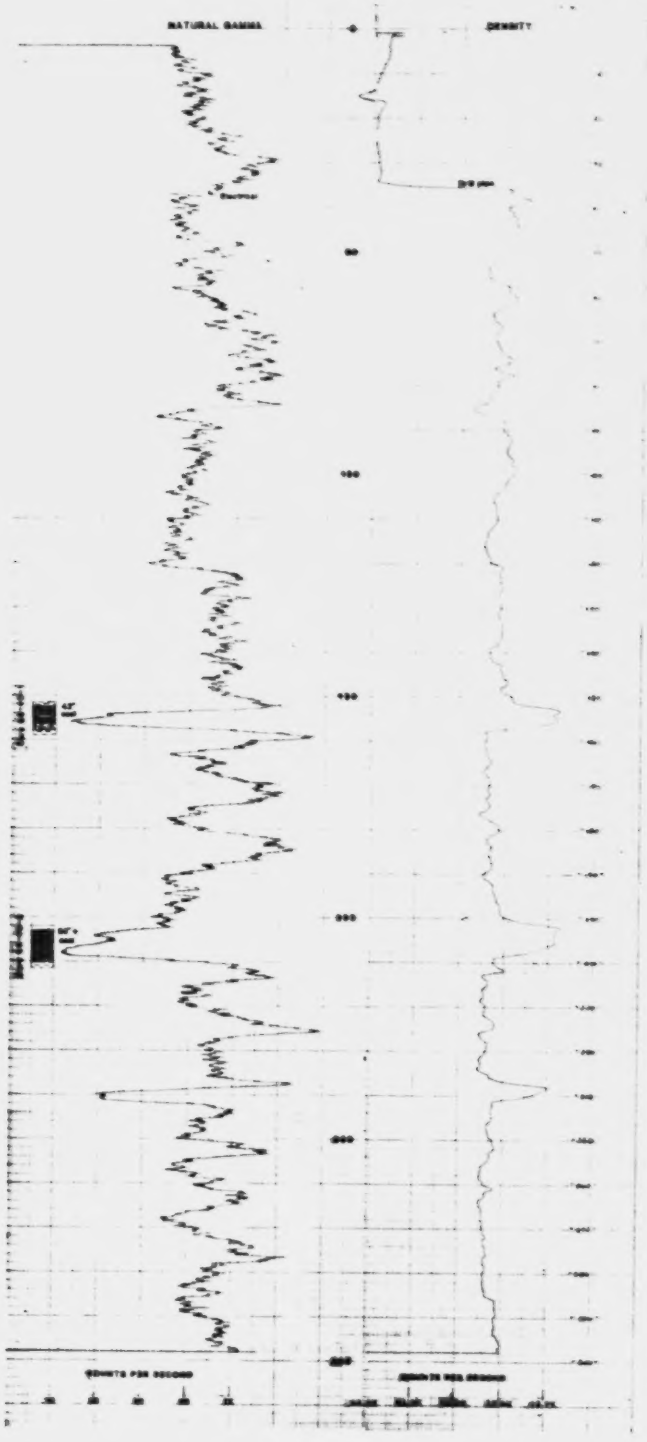

Figure 11.--Geophysical logs of hole GS-4.

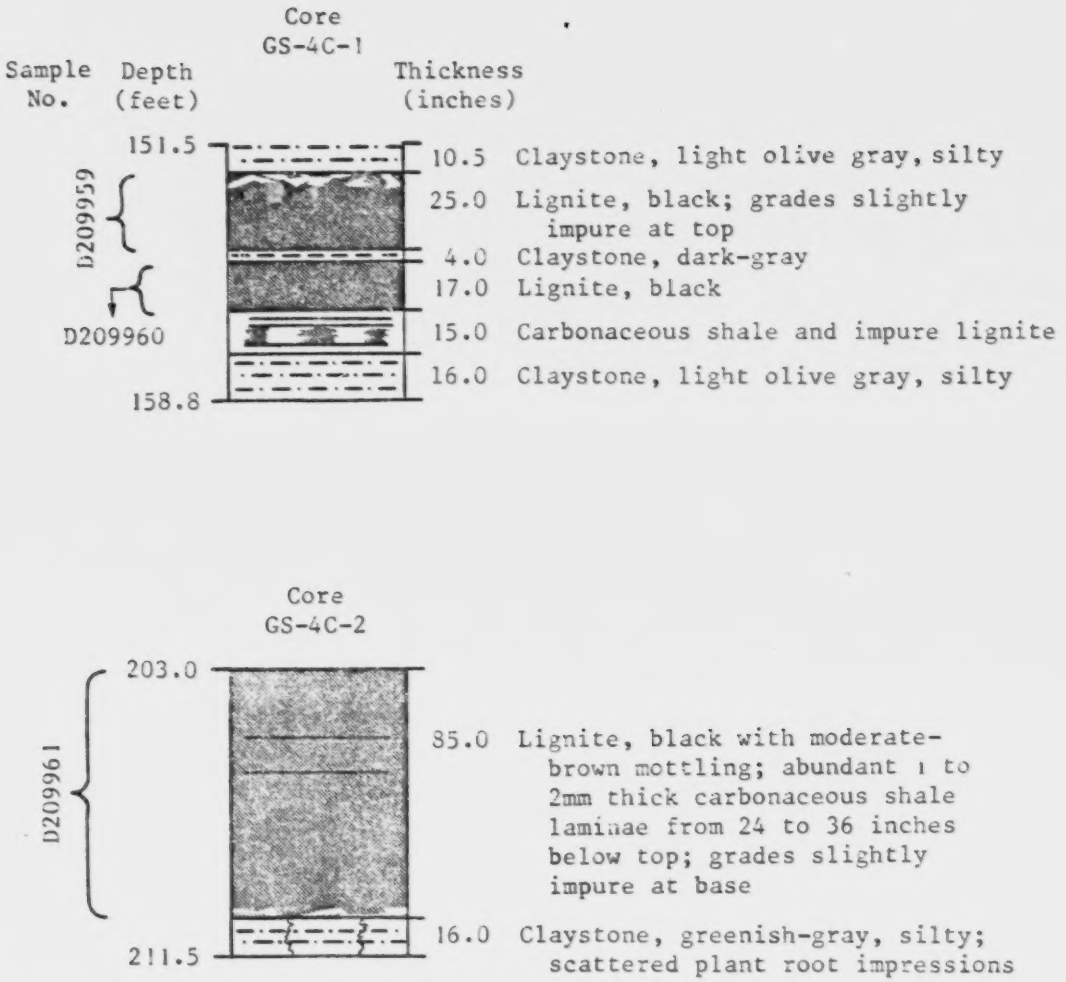

Figure 12.--Core and sample descriptions, core hole GS-4C, NE SE sec. 24, T. 28 N., R. 54 E., Roosevelt County, Montana.

Sample log

Hole no.: GS-5 Date: 10-27-78 State: Montana County: Roosevelt

Elev. (ground): 2010 ft Location: T. 28 N., R. 54 E., Sec. NW NW 2

Total depth: 220 ft Drilling medium: mud Offset core hole: none

Depth (feet)	Description
0-63.5	Gravel, sand, and clay, light-olive-gray, unconsolidated
63.5-65.5	Claystone, dark-yellowish-orange
65.5-76	Sandstone, dark-yellowish-orange, very fine grained, silty, micaceous, calcareous
76-78	Claystone, light-brownish-gray
78-84	Lignite, brownish-black
84-88	Claystone, light-gray; grades to siltstone in lower part
88-94	Sandstone, dark-yellowish-orange, very fine grained
94-99	Claystone, light-gray
99-109	Siltstone and claystone, light-gray, locally sandy, calcareous
109-116	Claystone, light-gray, calcareous, grades silty in middle of unit
116-126	Sandstone, light-gray, very fine grained, micaceous
126-132	Claystone, light- to medium-gray, slightly silty
132-143	Sandstone, very light gray, very fine grained
143-154	Claystone, light-gray; interbedded with siltstone in upper part
154-164	Siltstone, light- to medium-gray; includes some interbedded claystone
164-174	Sandstone, light-gray, very fine grained, silty, argillaceous
174-176.5	Claystone, medium-dark-gray
176.5-178	Lignite, black
178-185	Claystone, medium-gray to brownish-gray
185-190	Sandstone, light-gray, very fine grained, silty
190-205	Claystone, light-olive-gray; grades to siltstone and sandstone between 195 and 202 ft
205-216	Sandstone and siltstone, light-gray to light-olive-gray

Sample log--Continued

Depth (feet)	Description
216-220	Claystone, greenish-gray to brownish-gray
	Total depth 220 ft

Hole no.: GS-5 Date: 10/27/78 State: Montana County: Roosevelt
Elev. (ground): 2010 ft Location: T. 28 N., R. 54 E., Sec. NW NW 2
Total depth: 220 ft Bit size: 5.5 in Logging speed: 15 ft/min
Natural gamma: Time constant 4 Count range 50 cps
Density (gamma-gamma ray): Time constant 4 Count range 1,000 cps

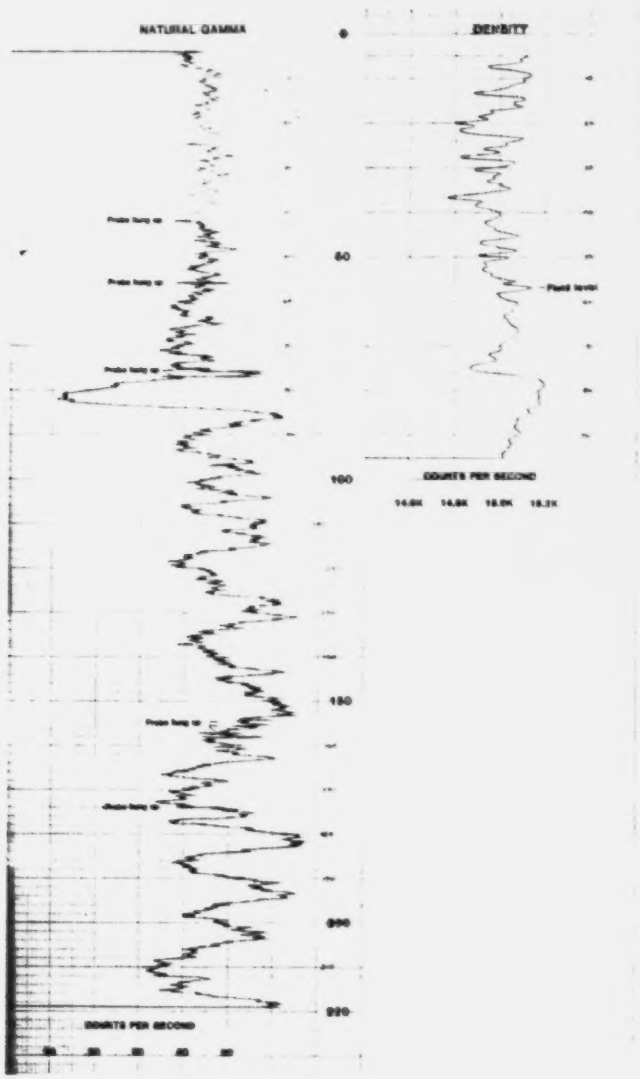

Figure 13.--Geophysical logs of hole GS-5.

Sample log

Hole no.: GS-6 Date: 10-28-78 State: Montana County: Roosevelt

Elev. (ground): 2161 ft Location: T. 29 N., R. 53 E., Sec. SE SE 35

Total depth: 415 ft Drilling medium: mud Offset core hole: GS-6C

Depth (feet)	Description
0-9	Gravel, sand, and clay, yellowish-gray, unconsolidated; some detrital coal fragments
9-18	Claystone, yellowish-gray to light-olive-gray; includes siltstone between 12 and 14 ft
18-40	Siltstone, yellowish-gray to light-olive-gray; includes some interbedded claystone; thin coal at 33 ft
40-58	Siltstone and sandstone, medium-light-gray, calcareous
58-67.5	Claystone, greenish-gray, slightly silty
67.5-71.1	Lignite, black; includes 2.5 in thick claystone parting in lower part; see core sample D209962 (fig. 15)
71.1-80	Claystone, greenish-gray
80-91	Sandstone and siltstone, medium-light-gray to yellowish-gray
91-94.5	Claystone, light-olive-gray, silty
94.5-106.5	Lignite, black with moderate-brown mottling; grades impure between 2.5 and 4.5 ft below top; includes 5 and 12 inch thick claystone partings between 104 and 105.8 ft; see core samples D209963 and D209964 (fig. 15)
106.5-141	Siltstone, light-gray to greenish-gray, calcareous; includes some interbedded olive-gray silty claystone; hard limestone concretions between 113 and 114 ft, 132 and 134 ft, and 140 and 141 ft
141-167	Claystone, medium-gray to olive-gray, silty; includes some light- to medium-light-gray siltstone, and scattered thin olive-gray limestone concretions
167-183	Siltstone, light- to medium-gray, calcareous; interbedded with silty claystone in middle to lower parts
183-198	Sandstone and siltstone, medium-gray; very fine grained sandstone at base grading upward to silty sandstone and siltstone at top; interbedded with silty claystone in middle part
198-200	Claystone, brownish-gray, silty
200-202	Lignite, black

Sample log--Continued

Depth (feet)	Description
202-210	Claystone, medium-light-gray, silty
210-217	Siltstone, light- to medium-light-gray, sandy; grades to silty sandstone in middle part
217-240	Silty claystone and siltstone, medium-light-gray to light-olive-gray; very silty claystone at top grading downward to siltstone
240-304	Sandstone and siltstone, light- to medium-gray, locally brownish-gray; scattered thin carbonaceous laminations; includes 3 to 4 ft thick intervals of brownish-gray claystone between 251 and 254 ft and 276 and 280 ft; thin limestone concretions between 290 and 300 ft
304-312	Claystone, medium-gray, slightly carbonaceous, silty
312-329	Sandstone, medium-light-gray, very fine grained, silty; scattered thin limestone concretions
329-334	Claystone, medium-gray to brownish-gray, silty; includes thin coal at 333 ft
334-338	Siltstone, medium-light-gray, sandy
338-342	Claystone, brownish-gray, silty
342-345	Lignite, grayish-black; slightly pyritic
345-354	Claystone, brownish-gray; grades silty at base
354-415	Sandstone, medium-light-gray to brownish-gray, very fine grained, silty; widely scattered thin carbonaceous laminations; very hard and dense limestone concretion at base
	Total depth 415 ft

Hole no.: GS-6 Date: 10/28/78 State: Montana County: Roosevelt
Elev. (ground): 2161 ft Location: T. 29 N., R. 53 E., Sec. SE SE 35
Total depth: 415 ft Bit size: 5.5 in Logging speed: 15 ft/min
Natural gamma: Time constant 4 Count range 50 cps
Density (gamma-gamma ray): Time constant 4 Count range 1,000 cps

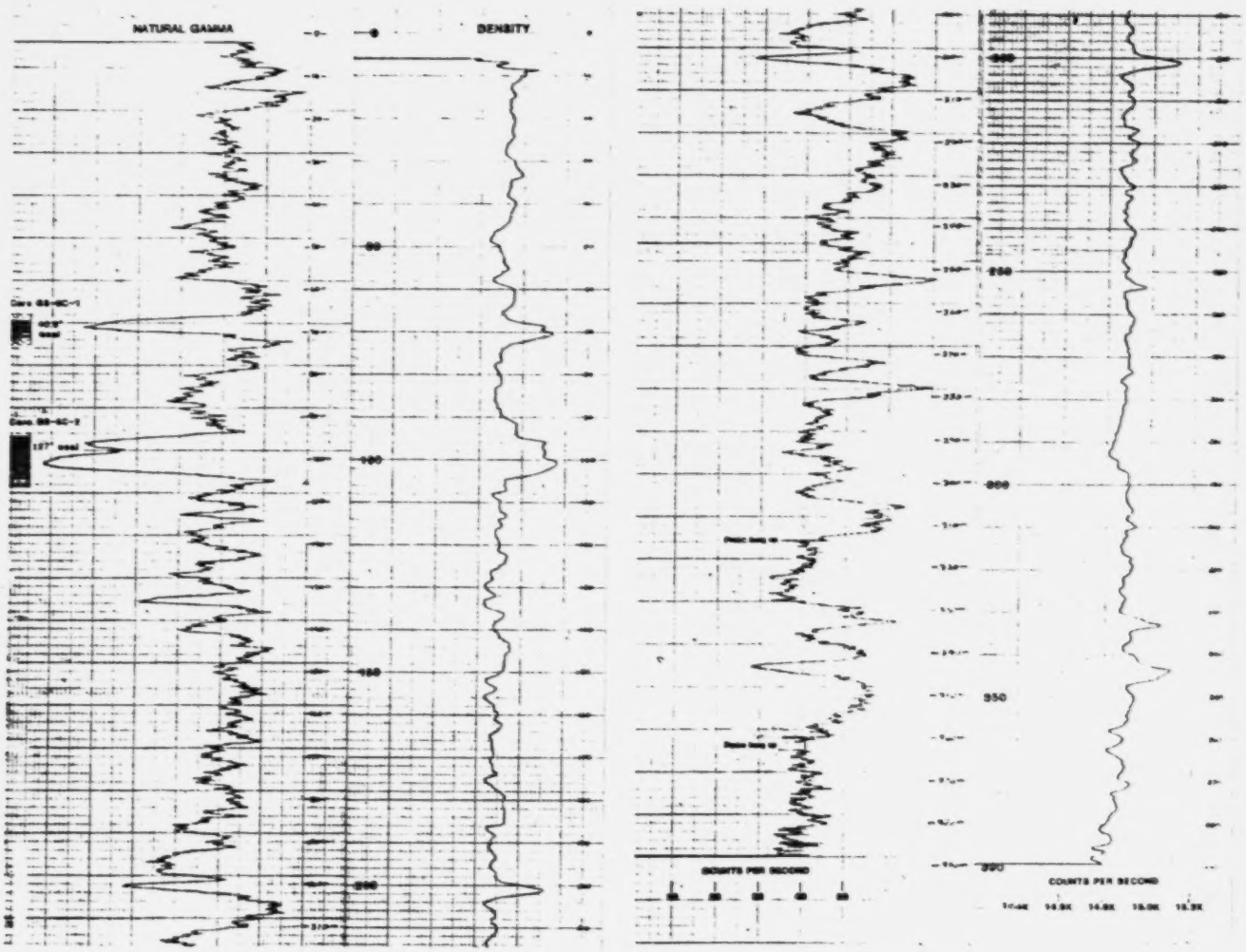

Figure 14.--Geophysical logs of hole GS-6.

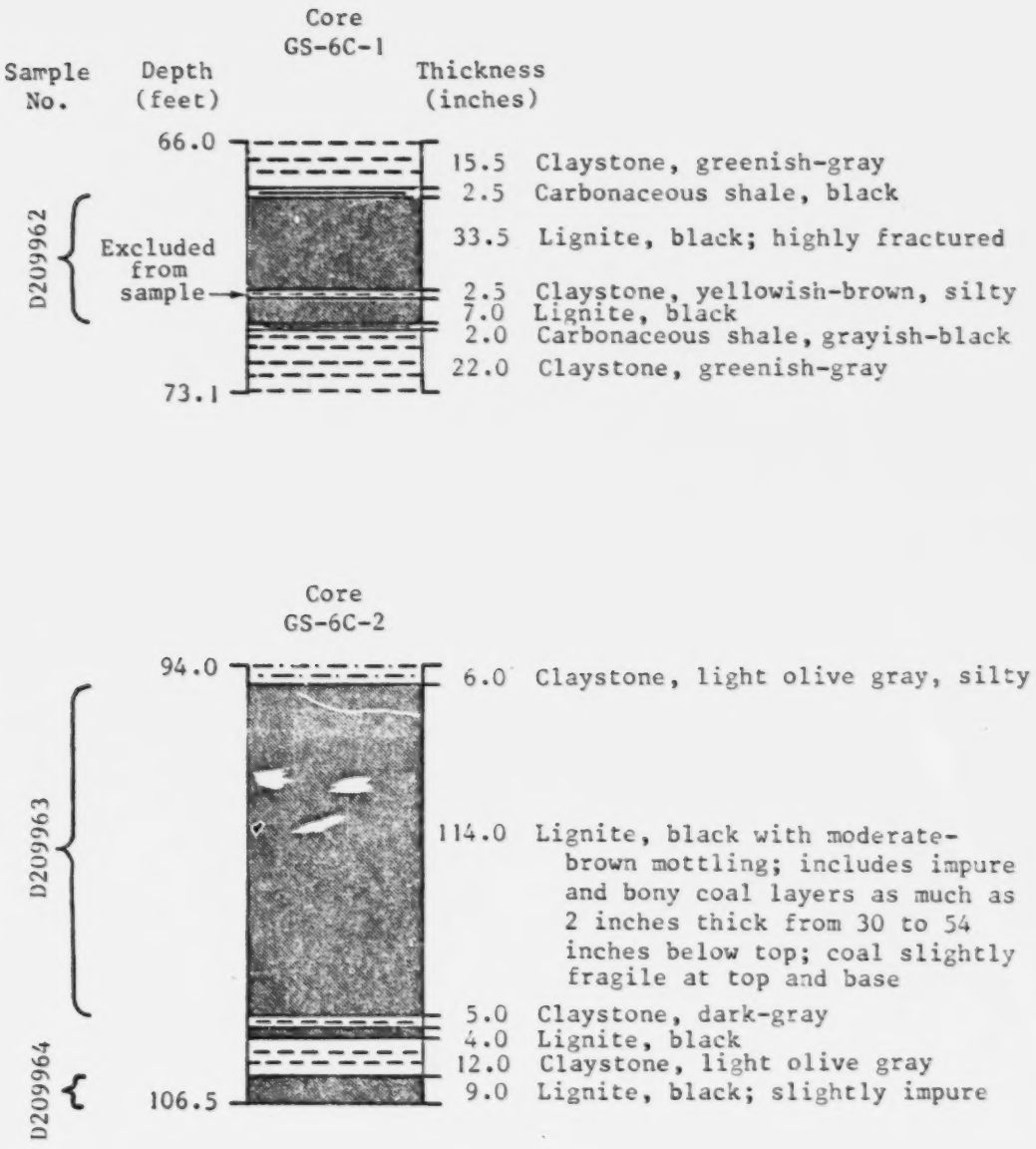

Figure 15.--Core and sample descriptions, core hole GS-6C, SE SE sec. 35, T. 29 N., R. 53 E., Roosevelt County, Montana.

Sample log

Hole no.: GS-7 Date: 10-30-78 State: Montana County: Roosevelt

Elev. (ground): 2239 ft Location: T. 29 N., R. 53 E., Sec. NW NW 35

Total depth: 260 ft Drilling medium: mud Offset core hole: none

Depth (feet)	Description
0-6	Gravel, sand, and clay, pale-yellowish-brown, unconsolidated
6-13	Siltstone, pale-brown to grayish-brown
13-18	Claystone, medium-gray to dark-yellowish-brown
18-29	Sandstone, greenish-gray to very pale orange, very fine grained, silty; traces of magnetite and chlorite (?); includes interbedded claystone between 22 and 24 ft
29-36	Siltstone and claystone, light-gray to light-olive-gray
36-54	Siltstone, light-gray to light-olive-gray, very sandy
54-63	Claystone and siltstone, meidum-dark-gray to light-olive-gray; claystone predominates at top and base grading to silty claystone and siltstone in middle of unit; scattered thin carbonaceous beds
63-66.5	Lignite, black
66.5-77	Claystone, light-greenish-gray, very silty in upper part
77-106	Siltstone and silty sandstone, light- to medium-light-gray, calcareous
106-114.5	Lignite, black; grades impure between 108 and 110 ft
114.5-118	Claystone, brownish-gray to medium-dark-gray
118-128	Sandstone, light-gray to light-olive-gray, very fine grained, silty
128-155	Siltstone, light-gray to yellowish-gray, sandy; includes some thinly interbedded silty calystone
155-157.5	Lignite, brownish-black, slightly impure
157.5-173	Sandstone and siltstone, light-gray to brownish-gray; grades to claystone at top
173-191	Siltstone and silty claystone, medium-light-gray to greenish-gray; siltstone in upper part grading downward to silty claystone at base
191-205	Sandstone, light- to medium-light-gray, very fine grained, silty
205-206	Lignite, black

Sample log--Continued

Depth (feet)	Description
206-208	Claystone, brownish-gray, carbonaceous
208-210	Lignite, black
210-218	Claystone and siltstone, medium-light-gray to brownish-gray; claystone at top and base grading to siltstone in middle of unit
218-260	Silty sandstone and siltstone, light-gray to brownish-gray; includes some thinly interbedded silty claystone
	Total depth 260 ft

Hole no.: GS-7 Date: 10/30/78 State: Montana County: Roosevelt
Elev. (ground): 2239 ft Location: T. 29 N., R. 53 E., Sec. NW NW 35
Total depth: 260 ft Bit size: 5.5 in Logging speed: 15 ft/min
Natural gamma: Time constant 4 Count range 50 cps
Density (gamma-gamma ray): Time constant 4 Count range 1,000 cps

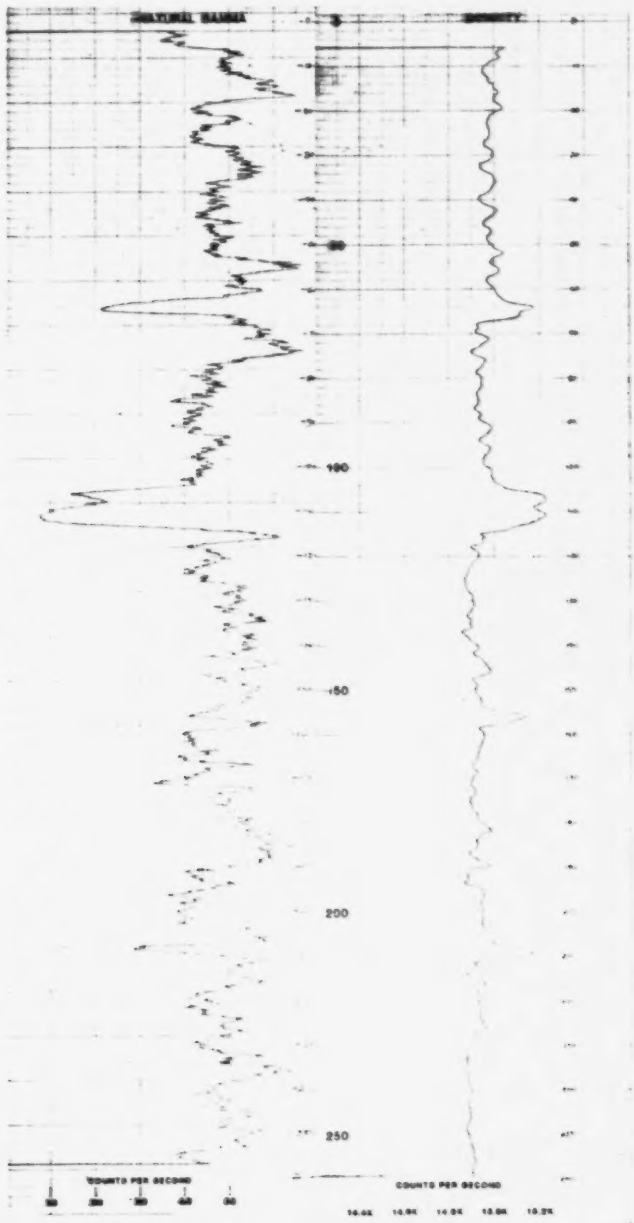

Figure 16.--Geophysical logs of hole GS-7.

Sample log

Hole no.: GS-8 Date: 10-16-78 State: Montana County: Roosevelt
Elev. (ground): 2360 ft Location: T. 28 N., R. 53 E., Sec. SE NW 10
Total depth: 320 ft Drilling medium: mud Offset core hole: GS-8C

Depth (feet)	Description
0-7	Fine gravel, sand, and clay, dark-yellowish-brown, unconsolidated
7-28	Claystone and siltstone, yellowish-gray, calcareous
28-42	Siltstone, yellowish-gray to grayish-yellow-green, sandy, micaceous, calcareous
42-43.5	Lignite, black
43.5-65	Claystone, light-gray to light-olive-gray, silty, finely micaceous; grades to siltstone between 50 and 55 ft
65-83	Siltstone, greenish-gray, calcareous; thin limestone concretion at 66 ft
83-87	Claystone, light-olive-gray
87-101	Siltstone, greenish-gray, sandy, calcareous
101-104	Lignite, black
104-111	Claystone, medium-gray to brownish-gray
111-115.5	Siltstone, greenish-gray; grades to silty claystone at top
115.5-116.5	Lignite, black
116.5-120	Claystone, medium-gray
120-156	Siltstone and claystone, light- to medium-gray, calcareous; sandy siltstone and silty claystone predominate
156-158.5	Lignite, black
158.5-178	Siltstone, light- to medium-light-gray, locally sandy; grades to silty claystone at top and base
178-184.2	Lignite, black; see core samples D209965 and D209966 (fig. 18)
184.2-190	Claystone, light-olive-gray; carbonaceous in upper part
190-202	Siltstone, medium-gray
202-206	Claystone, medium-dark-gray
206-207.2	Lignite, black

Sample log--Continued

Depth (feet)	Description
207.2-215	Claystone and siltstone, medium-gray to medium-dark-gray; claystone at top and base grading to siltstone in middle of unit
215-233	Siltstone, medium-gray to greenish-gray; grades sandy in lower part
233-246	Claystone, medium-gray; thin coal at 236 ft
246-250	Lignite and carbonaceous shale; impure coal at top and base separated by carbonaceous shale
250-258	Claystone, medium-gray, silty
258-320	Siltstone, medium-gray, very sandy; interbedded with claystone from 264 to 268 ft and 274 to 280 ft; limestone concretion at 273 ft; grades to silty sandstone at base
	Total depth 320 ft

Hole no.: GS-8 Date: 10/17/78 State: Montana County: Roosevelt
Elev. (ground): 2360 ft Location: T. 28 N., R. 53 E., Sec. SE NW 10
Total depth: 320 ft Bit size: 5.5 in Logging speed: 15 ft/min
Natural gamma: Time constant 4 Count range 50 cps
Density (gamma-gamma ray): Time constant 4 Count range 1,000 cps

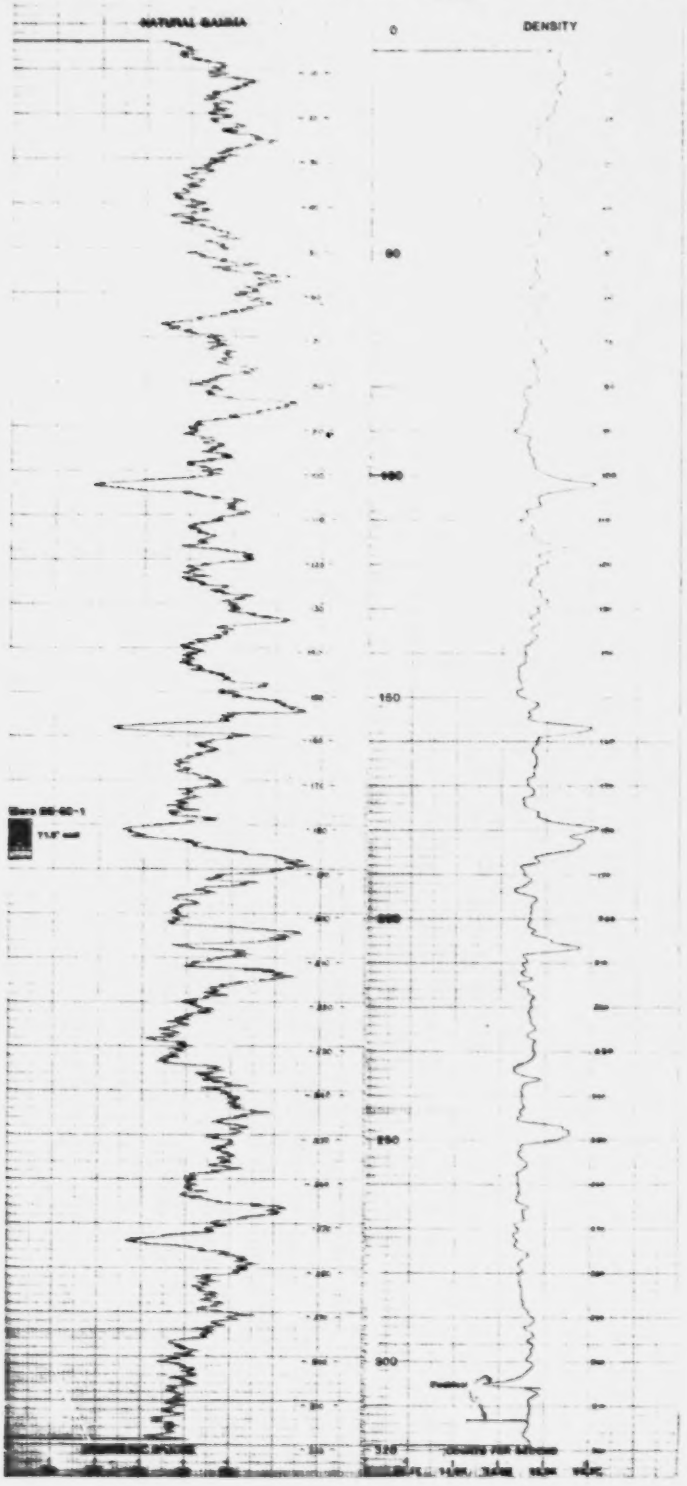

Figure 17.--Geophysical logs of hole GS-8.

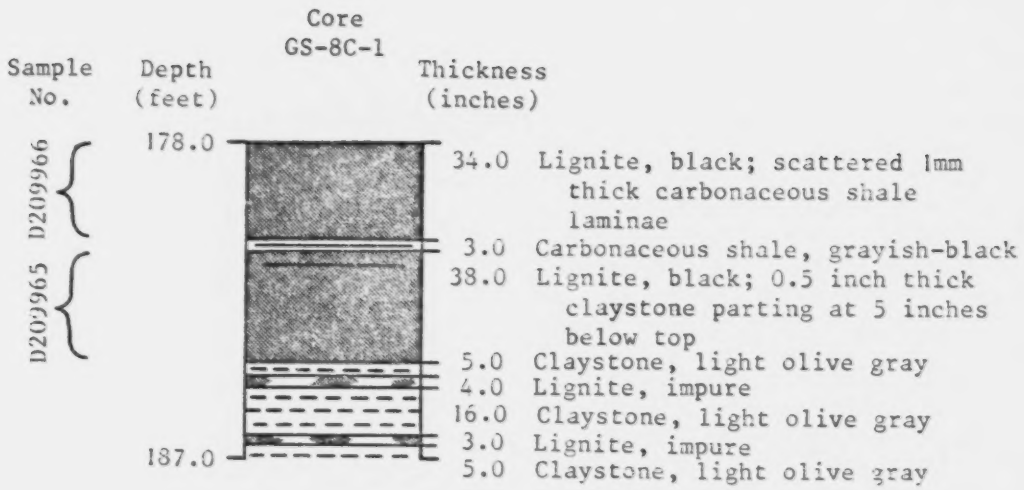

Figure 18.--Core and sample descriptions, core hole GS-8C, SE NW sec. 10, T. 28 N., R. 53 E., Roosevelt County, Montana.

Sample log

Hole no.: GS-9 Date: 10-31-78 State: Montana County: Roosevelt

Elev. (ground): 2122 ft Location: T. 29 N., R. 53 E., Sec. NE NW 33

Total depth: 330 ft Drilling medium: mud Offset core hole: GS-9C

Depth (feet)	Description
0-13	Gravel, sand, and silt, dark-yellowish-brown, unconsolidated
13-22	Siltstone and claystone, light-olive-gray to grayish-yellow; siltstone in upper part grades downward to claystone in lower part; thin coal at 20 ft
22-44	Sandstone, light-olive-gray, very fine grained, silty; interbedded with claystone between 30 and 33 ft; limestone concretion between 27 and 29 ft
44-53	Claystone, yellowish-gray to light-gray; limestone concretion between 48 and 50 ft
53-61	Sandstone and siltstone, yellowish-gray to light-olive-gray; sandstone in upper part grades downward to siltstone in lower part
61-64	Claystone, dark-gray; includes thin impure coal
64-69.5	Lignite and carbonaceous shale, dark-gray to black; geophysical logs indicate 1.5 ft of lignite at top, 2.5 ft of carbonaceous shale and impure coal in middle, and 1.5 ft of impure lignite at base
69.5-86	Claystone and siltstone, light- to medium-gray and brownish-gray; silty claystone predominates; includes thin limestone concretions between 82 and 84 ft
86-88	Lignite, black
88-92	Claystone, medium-gray to brownish-gray
92-121	Siltstone and sandstone, medium-light- to medium-gray; includes a thin coal at 98 ft and thinly interbedded silty claystone between 105 and 112 ft
121-127.5	Lignite, black; grades impure in lower part; see description of core GS-9C-1 (fig. 20)
127.5-140	Claystone, medium-light-gray to olive-gray, silty
140-150	Sandstone, medium-light-gray to light-olive-gray, very fine grained
150-170	Claystone and siltstone, medium-light-gray to light-olive-gray; thinely interbedded

Sample log--Continued

Depth (feet)	Description
170-187	Sandstone and siltstone, medium-light-gray; sandstone predominates in upper part, siltstone in lower part
187-197	Claystone, medium-gray to brownish-gray, silty; thin limestone concretion at 195 ft
197-213	Sandstone and siltstone, light-gray to brownish-gray; sandstone predominates in the upper part, siltstone in lower part; includes some scattered thin beds of medium-dark-gray claystone in middle to lower parts
213-218	Lignite and carbonaceous shale, black to brownish-gray; geophysical logs indicate 2 ft of lignite at top, 2 ft of carbonaceous shale and impure coal in middle, and about 1 ft of impure coal at base
218-224	Claystone, brownish-gray, silty
224-247	Sandstone and siltstone, medium-light- to medium-gray; siltstone at top grading downward to sandstone in middle and lower parts; hard limestone concretion between 238 and 240 ft
247-252	Claystone, medium-dark-gray, silty; includes thin impure coal
252-266	Sandstone and siltstone, light- to medium-gray; siltstone predominates in upper and lower parts, sandstone in the middle part
266-275.9	Claystone, medium-dark gray to brownish-black, silty; includes medium-dark-gray silty sandstone between 274 and 276 ft
275.9-282.6	Lignite, black; see samples numbered D209967 and D209968 (fig. 20)
282.6-304	Sandstone and siltstone, medium-gray to light-olive-gray; sandstone predominates in upper to middle parts, grading downward to siltstone in lower part; includes some thinly interbedded brownish-gray carbonaceous shale at 290 and 298 ft
304-308	Claystone, brownish-gray, silty
308-315	Siltstone, light-gray to brownish-gray; grades to sandstone at base
315-317	Claystone, brownish-gray, carbonaceous
317-319	Lignite, black
319-330	Claystone and siltstone, medium-light-gray to brownish-gray, thinly interbedded
	Total depth 330 ft

Hole no.: GS-9 Date: 10/31/78 State: Montana County: Roosevelt
Elev. (ground): 2122' Location: T. 29 N., R. 53 E., Sec. NE NW 33
Total depth: 330 ft Bit size: 4 3/4 in Logging speed: 15 ft/min
Natural gamma: Time constant 4 Count range 50 cps
Density (gamma-gamma ray): Time constant 1 Count range 1,000 cps

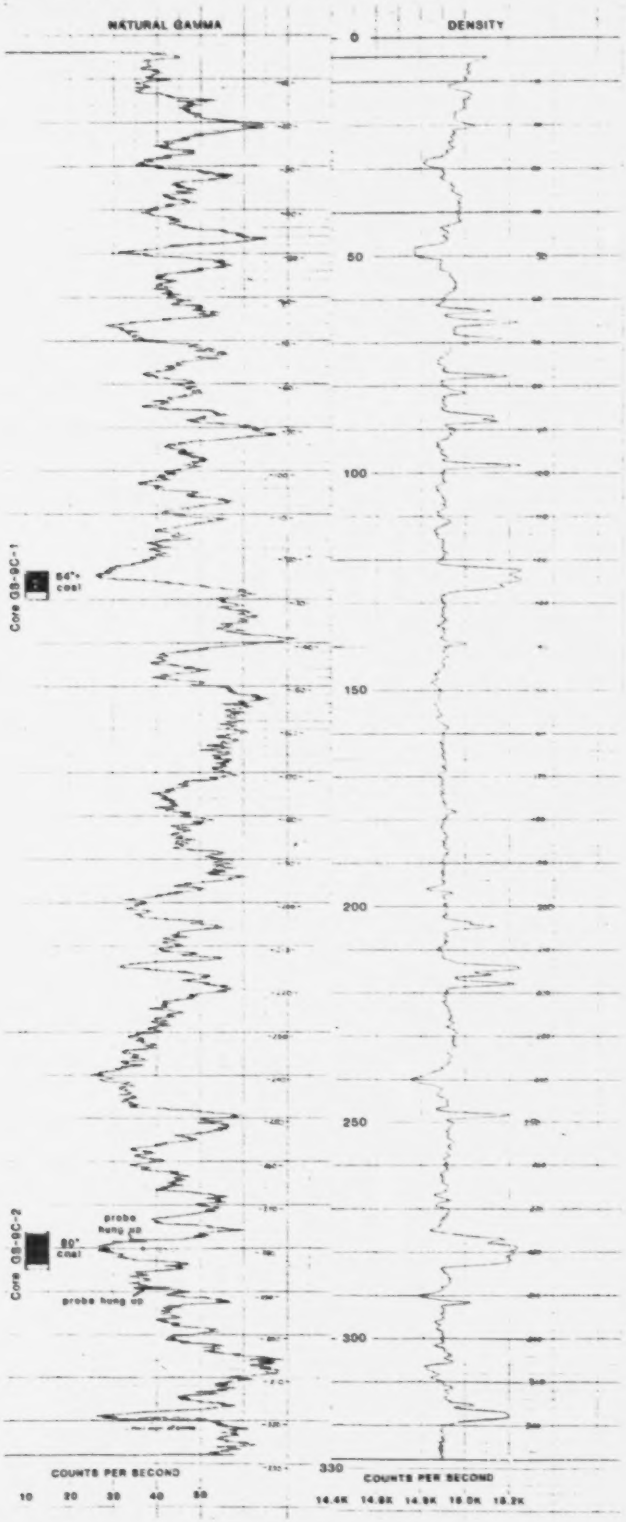

Figure 19.--Geophysical logs of hole GS-9.

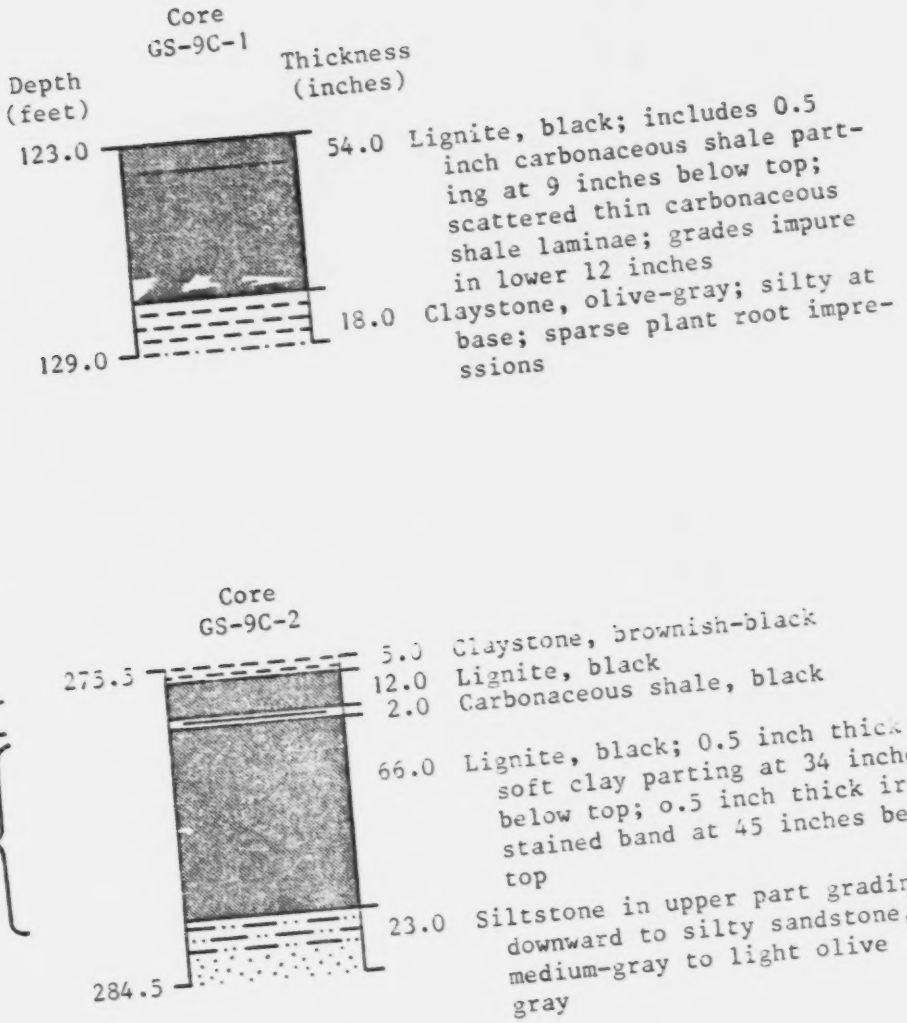
Core
GS-9C-1
Depth
(feet)
Thickness
(inches)
123.0
54.0 Lignite, black; includes 0.5 inch carbonaceous shale parting at 9 inches below top; scattered thin carbonaceous shale laminae; grades impure in lower 12 inches
18.0 Claystone, olive-gray; silty at base; sparse plant root impressions
129.0
Sample
No.
Core
GS-9C-2
D209967
D209968
275.5
5.0 Claystone, brownish-black
12.0 Lignite, black
2.0 Carbonaceous shale, black
66.0 Lignite, black; 0.5 inch thick soft clay parting at 34 inches below top; 0.5 inch thick iron-stained band at 45 inches below top
23.0 Siltstone in upper part grading downward to silty sandstone, medium-gray to light olive gray
284.5

Figure 20.--Core and sample descriptions, core hole GS-9C, NE NW sec. 33, T. 29 N., R. 53 E., Roosevelt County, Montana.

Sample log

Hole no.: GS-10 Date: 11-2-78 State: Montana County: Roosevelt

Elev. (ground): 2027 ft Location: T. 29 N., R. 53 E., Sec. NW NE 3

Total depth: 260 ft Drilling medium: mud Offset core hole: none

Depth (feet)	Description
0-15	Sand, silt, and fine gravel, grayish-yellow, unconsolidated
15-28	Coarse gravel, sand, and silt, grayish-yellow to dark-yellowish-brown, unconsolidated
28-42	Claystone and siltstone, medium-light-gray to yellowish-gray; silty claystone predominates in upper and lower parts, siltstone in middle part; includes thin coal at 36 ft
42-55	Sandstone, grayish-yellow, silty, calcareous
55-66	Claystone, light-gray, calcareous; includes thin coal at 62 ft; grades silty in lower part
66-150	Sandstone and siltstone, light- to medium-light-gray; sandstone predominates at top and siltstone in lower part, remainder of unit is interbedded silty sandstone and siltstone; scattered thin limestone concretions and several thin carbonaceous beds between 70 and 90 ft; includes some medium-gray silty claystone between 126 and 129 ft and at base
150-152	Lignite, black to brownish-black
152-186	Claystone, light- to medium-gray and brownish-gray, silty; includes some siltstone and numerous thin stringers of coal between 168 and 174 ft
186-188.5	Lignite, brownish-black
188.5-200	Sandstone, light-gray, very fine grained, silty; includes some medium-gray siltstone at top and between 194 and 197 ft
200-227	Claystone, very light- to light-gray, silty; includes fairly abundant thinly interbedded siltstone and scattered thin carbonaceous layers
227-229	Lignite, black to brownish-black
229-239	Siltstone, medium-light-gray to light-gray, calcareous
239-243	Claystone, brownish-black to olive-black, carbonaceous
243-260	Siltstone, light- to medium-gray, sandy, calcareous; grades to very fine grained sandstone between 252 and 254 ft
	Total depth 260 ft

Hole no.: GS-10 Date: 11/2/78 State: Montana County: Roosevelt

Elev. (ground): 2027 ft Location: T. 29 N., R. 53 E., Sec. NW NE 3

Total depth: 260 ft Bit size: 5½ in Logging speed: 15 ft/min

Natural gamma: Time constant 4 Count range 50 cps

Density (gamma-gamma ray): Time constant 4 Count range 1,000 cps

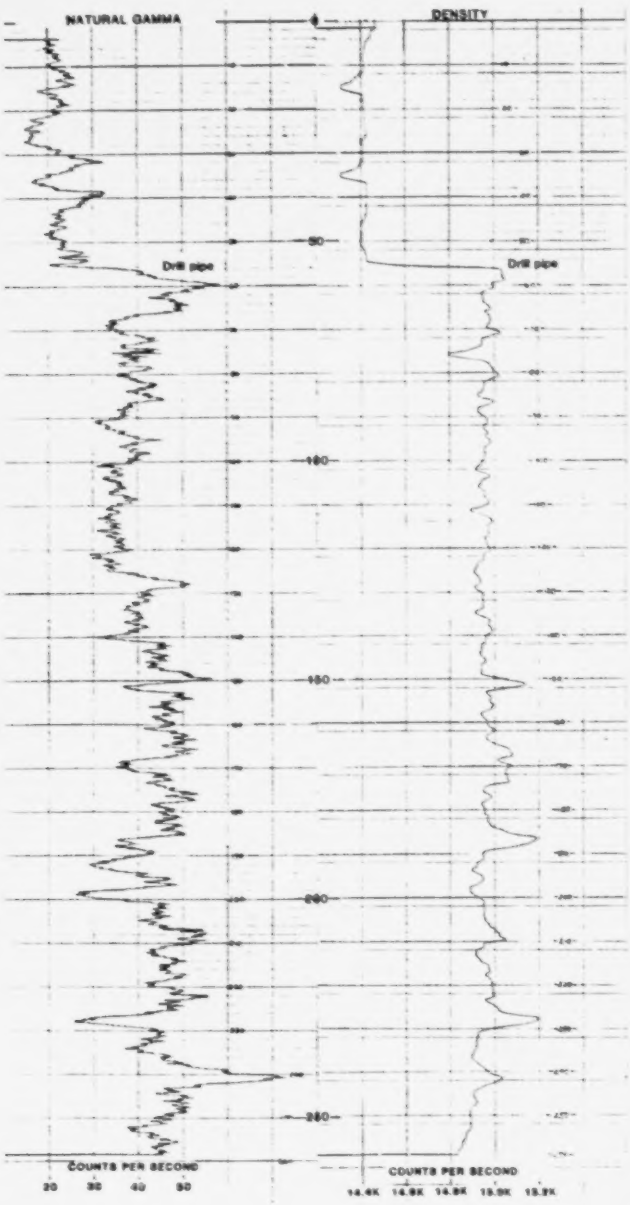

Figure 21.--Geophysical logs of hole GS-10.

Sample log

Hole no.: GS-12 Date: 11-6-78 State: Montana County: Roosevelt

Elev. (ground): 2478 ft Location: T. 30 N., R. 52 E., Sec. NE SE 7

Total depth: 500 ft Drilling medium: mud Offset core hole: none

Depth (feet)	Description
0-20	Gravel, sand, and clay, pale-yellowish-orange, unconsolidated
20-32	Claystone, light-gray to light-olive-gray; grades to siltstone at top and base
32-34	Lignite, black
34-73	Siltstone, grayish-orange and light-gray; scattered and thinly interbedded claystone; probable impure coal between 54.5 and 56.5 ft
73-110	Sandstone, light-gray, fine-grained; thin coal at 89 ft
110-117.5	Claystone, medium-gray, silty
117.5-121.5	Lignite and carbonaceous shale, dark-gray to black; geophysical logs indicate 10 inches of impure lignite at top, 20 inches of carbonaceous shale in middle, and about 18 inches of impure lignite at base
121.5-143	Siltstone, medium-gray; interbedded with claystone at top and between 131 and 133 ft; thin coal just above base
143-155	Siltstone and claystone, light- to medium-gray; siltstone in upper part grades downward to silty claystone in lower part
155-200	Sandstone and siltstone, light-gray; grades to siltstone at top and base, sandstone predominates elsewhere; includes silty claystone between 171 and 173 ft
200-204	Lignite, grayish-black to black
204-215	Siltstone and claystone, light-gray; sandy siltstone in upper part grading downward to silty claystone at base
215-217	Lignite, brownish-black, slightly impure
217-223	Siltstone, light-gray, sandy
223-227	Claystone, light- to medium-gray, silty
227-271	Sandstone and siltstone, light-gray; sandstone predominates in upper and lower parts; chiefly siltstone and sandy siltstone in middle part with some thinly interbedded silty claystone; thin limestone concretion at 230 ft
271-278	Claystone, medium-gray; silty in upper part; impure coal between 273 and 274 ft

Sample log--Continued

Depth (feet)	Description
278-294	Siltstone and silty sandstone, light-gray, calcareous, very finely micaceous; includes thin silty claystone at base
294-301	Lignite, impure lignite, and carbonaceous shale, black to brownish-black; geophysical logs indicate about 3.5 ft of impure coal and carbonaceous shale in upper part, and about 3.5 ft of lignite in lower part
301-306	Claystone, medium-gray to brownish-gray
306-319	Siltstone, silty sandstone, and claystone, light- to medium-gray; siltstone and silty sandstone in upper part grading downward to siltstone and silty claystone at base
319-327	Lignite and carbonaceous shale, black to grayish-black; geophysical logs indicate 3 ft of lignite at top, 2 ft of carbonaceous shale in middle of unit, and 3 ft of lignite in lower part
327-376	Siltstone and silty sandstone, light- to medium-gray; siltstone predominates with silty sandstone locally more abundant in middle to lower parts; includes sparse thinly interbedded silty claystone; scattered thin limestone concretions between 345 and 365 ft
376-378	Lignite, grayish-black, slightly impure
378-421	Siltstone and sandstone, light-gray; siltstone in upper part grades downward to silty sandstone in middle, and to siltstone and silty claystone in lower part; thin impure coal at 388 ft
421-428	Lignite and carbonaceous shale; black to grayish-black; geophysical logs indicate 2.5 ft lignite at top, 1.5 ft carbonaceous shale in middle, and 3 ft of lignite in lower part
428-459	Claystone and siltstone, medium- to dark-gray; claystone in upper part grades downward to siltstone in middle, and to silty claystone in lower part
459-482	Siltstone and sandstone, light- to medium-gray, thinly interbedded; grades to silty claystone at base
482-484	Carbonaceous shale and impure coal, black to grayish-black
484-487	Claystone, dark-gray
487-490.5	Lignite and carbonaceous shale, black to grayish-black; geophysical logs indicate about 1.8 ft of slightly impure lignite at top, about 0.8 ft carbonaceous shale in middle, and about 0.9 ft of impure lignite at base of unit
490.5-500	Siltstone and silty claystone, medium-gray, thinly interbedded
	Total depth 500 ft

Hole no.: GS-12 Date: 11/6/78 State: Montana County: Roosevelt
Elev. (ground): 2478 ft Location: T. 30 N., R. 52 E., Sec. SE 7
Total depth: 500 ft Bit size: 5½ in Logging speed: 15 ft/min
Natural gamma: Time constant 4 Count range 50 cps
Density (gamma-gamma ray): Time constant 1 Count range 1,000 cps

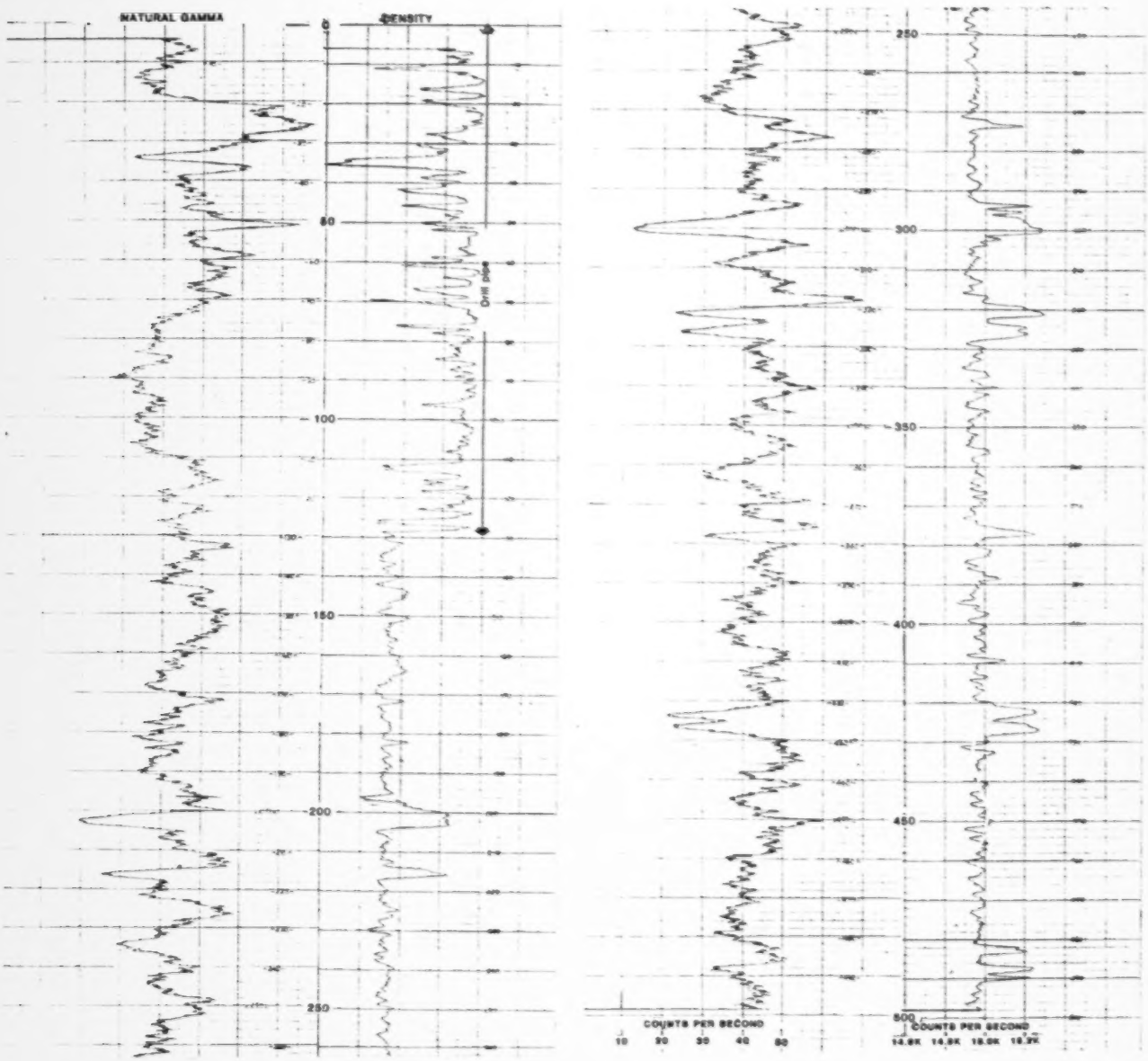

Figure 22.--Geophysical logs of hole GS-12.

Sample log

Hole no.: GS-15 Date: 11-4-78 State: Montana County: Roosevelt

Elev. (ground): 2375 ft Location: T. 31 N., R. 52 E., Sec. SE SW 26

Total depth: 480 ft Drilling medium: mud Offset core hole: none

Depth (feet)	Description
0-60	Gravel, sand, silt, and clay, light-olive-gray to pale-yellowish-brown, unconsolidated
60-76	Sandstone and silty claystone, medium-light-gray to very pale orange; sandstone predominates at top and in lower part, grades to silty claystone in middle and at base
76-100	Claystone, yellowish-gray to medium-light-gray, silty
100-106	Siltstone and silty claystone, medium-gray; trace of coal in cuttings but no indication of coal in geophysical logs
106-137	Sandstone, yellowish-gray, very fine grained, silty; includes some thinly interbedded siltstone in upper part
137-144	Claystone and impure lignite, medium-gray to grayish-black; claystone in upper part grades downward to silty claystone, and about 14 inches of impure lignite at base
144-159	Siltstone, light-gray, calcareous; thin limestone concretions at 146, 152, and 156 ft
159-180	Claystone, light- to medium-gray, silty; grades downward to siltstone at base
180-193	Siltstone, light-gray; grades downward to sandy siltstone at base
193-215	Sandstone, light-gray, very fine grained, silty
215-236	Claystone, medium- to dark-gray; includes thin impure coals at 217 and 223 ft; grades silty at top and in lower part
236-250	Sandstone, light-gray, very fine grained, silty; grades to siltstone at top and base; trace of coal in 245-250 ft cuttings sample
250-265	Siltstone and claystone, light- to medium-gray; siltstone in upper part grades downward to claystone in lower part; trace of coal in 250-255 ft cuttings sample
265-285	Siltstone and sandstone, light- to medium-light-gray; siltstone in upper part grades downward to silty sandstone in lower part
285-294	Claystone, light- to medium-gray; grades silty and includes some thinly interbedded siltstone in middle part
294-298	Lignite, grayish-brown to black, trace of pyrite

Sample log--Continued

Depth (feet)	Description
298-337	Siltstone and claystone, light- to medium-light-gray; siltstone in upper part grades downward to silty claystone; limestone concretions between 316-318 ft, 326-327 ft, and 336-337 ft
337-370	Siltstone, light- to medium-gray, calcareous, finely micaceous; some thinly interbedded silty sandstone; thin coals at 354 ft and 369 ft
370-390	Claystone, medium-light-gray; very silty in upper part; includes bed of lignite between 379 and 380 ft
390-400	Siltstone and claystone, medium-light-gray; claystone at top grades downward to silty claystone and siltstone in lower part
400-403	Lignite, black
403-409	Claystone, dusky-yellowish-brown, slightly carbonaceous
409-429	Siltstone, light-gray, calcareous; includes some thinly interbedded silty sandstone in lower part
429-434	Claystone, medium-gray, silty in upper part
434-437	Lignite, grayish-black to black
437-455	Siltstone and claystone, light- to medium-gray; slightly carbonaceous claystone at top grades downward to siltstone in middle and lower parts
455-460.5	Lignite, grayish-black to black, slightly impure
460.5-480	Claystone and siltstone, medium-gray, thinly interbedded
	Total depth 480 ft

Hole no.: GS-15 Date: 11/4/78 State: Montana County: Roosevelt

Elev. (ground): 2375 ft Location: T. 31 N., R. 52 E., Sec. SW 26

Total depth: 480 ft Bit size: 5½ in Logging speed: 15 ft/min

Natural gamma: Time constant 4 Count range 50 cps

Density (gamma-gamma ray): Time constant 1 Count range 1,000 cps

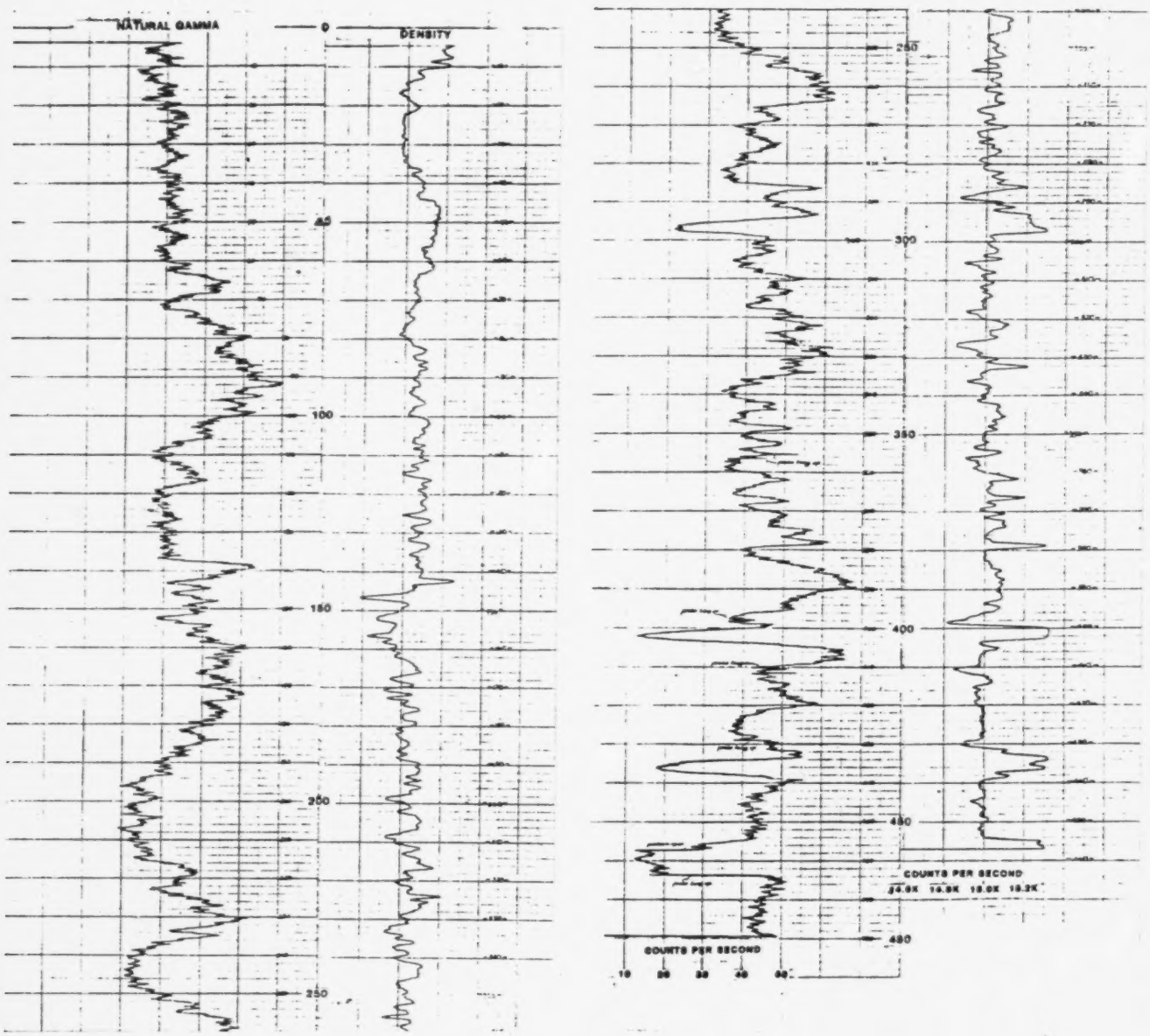

Figure 23.--Geophysical logs of hole GS-15.

Coal samples and analyses

Seven core holes were drilled in the southeastern part of the Fort Peck Indian Reservation in 1978 to obtain fresh samples of coal for chemical analysis. The locations of the core holes are shown in figure 3. Sixteen samples of coal collected from cores from the Fort Union Formation are listed in table 1. Proximate and ultimate analyses, and heat-of-combustion, air-dried-loss, forms-of-sulfur, and ash-fusion-temperature determinations on the 16 samples of coal made by the U.S. Department of Energy, Pittsburgh, Pa., are shown in table 2. Analyses of the 16 coal samples for ash content and 29 major and minor oxides in the laboratory ash listed in table 3, and analyses of nine trace elements in whole coal listed in table 4 were provided by U.S. Geological Survey laboratories, Lakewood, Colo. Analytical procedures used by the U.S. Geological Survey are described in Swanson and Huffman (1976).

Table 5 contains the data listed in table 3 converted to a whole-coal basis, plus the whole-coal analyses listed in table 4. Table 6 lists 26 additional elements not included in tables 3, 4, and 5, which were looked for but not found. These elements, if present, are in concentration less than their lower limits of detection.

The apparent rank of all coals analyzed is lignite A, according to specifications of the American Society for Testing and Materials (1978).

Table 1.--U.S. Geological Survey sample numbers, core-hole numbers, core-hole locations, and depth of sampled interval for 16 samples of coal from the Fort Union Formation, Fort Peck Indian Reservation, Roosevelt County, Montana

[All samples were collected from cores; 1 foot = 0.3048 meter]

USGS sample No.	USGS core-hole No.	Core hole location	Depth interval (feet)
D209953	GS-2C	NW 1/4 SE 1/4 sec. 23, T. 28 N., R. 53 E.	244.4-247.5
D209954	GS-2C'	----------do----------	243.7-248.8
D209955	--do--	----------do----------	290.0-294.5
D209956	--do--	----------do----------	304.4-311.0
D209957	GS-1C	NW 1/4 NW 1/4 sec. 21, T. 28 N., R. 54 E.	117.2-126.0
D209958	--do--	----------do----------	134.7-143.7
D209959	GS-4C	NE 1/4 SE 1/4 sec. 24, T. 28 N., R. 54 E.	152.4-154.5
D209960	--do--	----------do----------	154.8-156.2
D209961	--do--	----------do----------	203.0-210.1
D209962	GS-6C	SE 1/4 SE 1/4 sec. 35, T. 29 N., R. 53 E.	67.5- 71.1
D209963	--do--	----------do----------	94.5-104.0
D209964	--do--	----------do----------	105.7-106.5
D209965	GS-8C	SE 1/4 NW 1/4 sec. 10, T. 28 N., R. 53 E.	178.0-180.8
D209966	--do--	----------do----------	181.1-184.2
D209967	GS-9C	NE 1/4 NW 1/4 sec. 33, T. 29 N., R. 53 E.	275.9-276.9
D209968	--do--	----------do----------	277.1-282.6

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, and ash-fusion-temperature determinations for 16 coal samples from the Fort Union Formation, Fort Peck Indian Reservation, Roosevelt County, Montana

[All analyses in percent except heat of combustion and ash-fusion temperatures. For each sample number, the analyses are reported three ways: first, as received; second, moisture free; and third, moisture and ash free. N/A, not applicable; L, less than value shown. All analyses by U.S. Department of Energy, 1979]

USGS sample No.	Proximate analysis				Ultimate analysis					Heat of combustion
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Btu/lb
D209953	34.3	23.9	33.4	8.4	6.4	42.6	0.6	40.8	1.2	7020
	N/A	36.4	50.8	12.8	3.9	64.8	.9	15.7	1.9	10680
	N/A	41.8	58.2	N/A	4.5	74.3	1.1	18.0	2.1	12250
D209954	35.4	23.9	32.9	7.8	6.7	41.5	.6	42.5	.9	6920
	N/A	37.0	51.0	12.0	4.3	64.3	1.0	17.2	1.4	10710
	N/A	42.0	58.0	N/A	4.8	73.1	1.1	19.4	1.6	12170
D209955	31.8	23.5	32.7	12.0	5.9	41.4	.6	39.3	.9	6800
	N/A	34.5	48.0	17.5	3.4	60.7	.9	16.1	1.3	9980
	N/A	41.9	58.1	N/A	4.1	73.7	1.1	19.5	1.6	12100
D209956	32.7	22.5	31.8	13.0	6.3	39.8	.6	39.8	.5	6500
	N/A	33.4	47.3	19.3	3.9	59.2	.8	16.0	.7	9660
	N/A	41.4	58.6	N/A	4.9	73.4	1.0	19.8	.9	11980
D209957	35.6	25.1	28.2	11.1	6.9	38.0	.7	43.0	.4	6450
	N/A	39.0	43.7	17.3	4.5	58.9	1.0	17.6	.7	10010
	N/A	47.1	52.9	N/A	5.5	71.2	1.2	21.3	.8	12100
D209958	35.3	26.2	31.5	7.0	6.8	40.8	.7	44.3	.3	6840
	N/A	40.6	48.5	10.9	4.5	63.2	1.1	19.9	.5	10590
	N/A	45.5	54.5	N/A	5.0	70.9	1.2	22.3	.5	11880
D209959	35.5	25.7	29.6	9.2	6.9	39.6	.7	42.9	.7	6670
	N/A	39.9	45.8	14.3	4.7	61.4	1.0	17.6	1.1	10340
	N/A	46.6	53.4	N/A	5.4	71.6	1.2	20.5	1.3	12060
D209960	34.3	26.4	33.4	5.9	6.6	43.1	.7	43.3	.3	7170
	N/A	40.1	50.9	9.0	4.3	65.6	1.1	19.5	.4	10910
	N/A	44.1	55.9	N/A	4.7	72.1	1.2	21.5	.5	11990

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, and ash-fusion-temperature determinations for 16 coal samples from the Fort Union Formation, Fort Peck Indian Reservation, Roosevelt County, Montana--Continued

USGS sample No.	Air dried loss	Forms of sulfur			Ash fusion temperature, °F		
		Sulfate	Pyritic	Organic	Initial deformation	Softening	Fluid
D209953	27.2	0.02	0.82	0.39	2,000	2,110	2,190
	N/A	.03	1.24	.59			
	N/A	.03	1.42	.67			
D209954	28.0	.01L	.50	.43	2,050	2,170	2,280
	N/A	.01L	.77	.67			
	N/A	.01L	.87	.76			
D209955	24.3	.01L	.57	.35	1,910	2,020	2,140
	N/A	.01L	.83	.51			
	N/A	.01L	1.01	.61			
D209956	25.1	.01L	.17	.29	2,030	2,150	2,270
	N/A	.01L	.26	.44			
	N/A	.01L	.32	.54			
D209957	28.1	.01	.16	.26	2,110	2,230	2,320
	N/A	.01	.25	.40			
	N/A	.01	.30	.48			
D209958	27.8	.01L	.12	.19	2,080	2,170	2,280
	N/A	.01L	.18	.30			
	N/A	.01L	.20	.33			
D209959	28.0	.01L	.14	.56	1,910	2,020	2,110
	N/A	.01L	.21	.87			
	N/A	.01L	.25	1.02			
D209960	26.3	.01L	.03	.25	2,200	2,290	2,370
	N/A	.01L	.04	.38			
	N/A	.01L	.05	.42			

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, and ash-fusion-temperature determinations for 16 coal samples from the Fort Union Formation, Fort Peck Indian Reservation, Roosevelt County, Montana--Continued

USGS sample No.	Proximate analysis				Ultimate analysis					Heat of combustion
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Btu/lb
D209961	36.3	24.7	30.7	8.3	6.7	39.4	.7	44.6	.3	6660
	N/A	38.8	48.2	13.0	4.2	61.9	1.1	19.3	.4	10460
	N/A	44.6	55.4	N/A	4.8	71.2	1.2	22.2	.5	12030
D209962	34.7	24.9	27.9	12.5	6.3	37.7	.7	40.7	2.1	6410
	N/A	38.1	42.8	19.1	3.8	57.7	1.0	15.1	3.2	9800
	N/A	47.1	52.9	N/A	4.7	71.4	1.3	18.7	3.9	12120
D209963	36.3	25.4	30.7	7.6	6.9	40.1	.7	44.3	.5	6690
	N/A	39.9	48.2	11.9	4.5	62.9	1.0	18.9	.8	10490
	N/A	45.3	54.7	N/A	5.1	71.4	1.2	21.4	1.0	11910
D209964	35.9	24.5	28.1	11.5	6.6	36.5	.5	43.2	1.7	6250
	N/A	38.2	43.9	17.9	4.0	57.0	.8	17.5	2.7	9760
	N/A	46.6	53.4	N/A	4.9	69.5	.9	21.3	3.3	11890
D209965	36.3	25.9	29.5	8.3	6.7	39.5	.7	44.4	.5	6610
	N/A	40.7	46.3	13.0	4.1	62.0	1.0	19.1	.7	10380
	N/A	46.8	53.2	N/A	4.8	71.3	1.2	21.9	.9	11930
D209966	33.7	22.3	24.6	19.4	6.3	32.7	.6	40.2	.8	5490
	N/A	33.6	37.1	29.3	3.9	49.3	.9	15.4	1.2	8290
	N/A	47.5	52.5	N/A	5.5	69.7	1.3	21.8	1.7	11710
D209967	28.5	20.6	25.0	25.9	5.3	32.2	.5	34.6	1.5	5280
	N/A	28.8	34.9	36.3	3.0	45.0	.8	12.9	2.1	7380
	N/A	45.3	54.7	N/A	4.7	70.7	1.2	20.3	3.2	11590
D209968	31.9	23.0	29.4	15.7	6.1	37.2	.6	38.9	1.5	6250
	N/A	33.8	43.1	23.1	3.8	54.6	.9	15.5	2.2	9170
	N/A	43.9	56.1	N/A	4.9	70.9	1.2	20.1	2.9	11920

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, and ash-fusion-temperature determinations for 16 coal samples from the Fort Union Formation, Fort Peck Indian Reservation, Roosevelt County, Montana--Continued

USGS sample No.	Air dried loss	Forms of sulfur			Ash fusion temperature, °F		
		Sulfate	Pyritic	Organic	Initial deformation	Softening	Fluid
D209961	28.6	.01L	.02	.25	1,960	2,070	2,160
	N/A	.01L	.03	.40			
	N/A	.01L	.04	.46			
D209962	27.2	.01	.84	1.22	1,890	1,980	2,070
	N/A	.02	1.29	1.87			
	N/A	.02	1.60	2.31			
D209963	28.6	.01L	.16	.37	1,910	2,120	2,210
	N/A	.01L	.26	.58			
	N/A	.01L	.29	.65			
D209964	28.5	.08	.49	1.16	1,980	2,090	2,180
	N/A	.13	.76	1.82			
	N/A	.16	.92	2.21			
D209965	28.5	.01L	.04	.44	2,160	2,280	2,360
	N/A	.01L	.06	.69			
	N/A	.01L	.06	.79			
D209966	26.9	.01L	.12	.68	2,240	2,350	2,440
	N/A	.01L	.19	1.02			
	N/A	.01L	.26	1.44			
D209967	21.7	.07	.39	1.00	2,120	2,210	2,320
	N/A	.10	.55	1.40			
	N/A	.16	.86	2.20			
D209968	24.3	.01	.25	1.27	2,000	2,110	2,200
	N/A	.01	.37	1.86			
	N/A	.01	.48	2.42			

Table 3.--Major- and minor-oxide and trace element composition of the laboratory ash of 16 coal samples from the Fort Union Formation, Fort Peck Indian Reservation, Roosevelt County, Montana

[Lignite ashed at 525°C. L, less than value shown; N, not detected. S after element title indicates determinations by semiquantitative emission spectrography. The spectrographic results are to be identified with geometric brackets whose boundaries are part of the ascending series 0.12, 0.18, 0.26, 0.38, 0.56, 0.83, 1.2, etc. but reported as midpoints of the brackets, 0.1, 0.15, 0.2, 0.3, 0.5, 0.7, 1.0, etc. Precision of the spectrographic data is plus-or-minus one bracket at 68 percent or plus-or-minus two brackets at 95 percent confidence level. All analyses by U.S. Geological Survey laboratories, Lakewood, Colorado]

USGS sample No.	Ash (percent)	SiO_2 (percent)	Al_2O_3 (percent)	CaO (percent)	MgO (percent)	Na_2O (percent)	K_2O (percent)	Fe_2O_3 (percent)	TiO_2 (percent)	P_2O_5 (percent)
D209953	10.7	16	10	15	4.32	9.32	0.25	10	0.27	0.09L
D209954	9.4	12	7.4	14	3.98	9.32	.26	14	.23	.09L
D209955	16.0	39	19	8.5	2.49	5.40	1.1	5.1	.45	.09L
D209956	15.6	41	21	10	2.66	5.94	1.2	2.7	.77	.09L
D209957	12.9	15	18	13	6.47	0.54	1.3	5.7	.63	.23
D209958	9.0	28	16	20	9.13	0.68	.66	4.3	.57	.18
D209959	10.8	28	13	13	4.48	6.35	1.1	9.2	.53	.46
D209960	7.4	15	12	22	6.31	8.64	.36	7.0	.42	.21
D209961	10.9	34	17	14	4.81	7.83	.83	4.4	.58	.09L
D209962	16.2	30	13	10	4.81	0.81	1.1	12	.43	.14
D209963	10.1	26	15	18	8.13	0.81	.53	4.6	.55	1.01
D209964	15.6	21	7.4	7.3	3.82	0.54	1.1	29	.37	.09L
D209965	11.4	32	21	15	6.31	0.68	.99	3.1	.62	.09L
D209966	27.5	51	21	6.3	2.82	0.68	1.8	2.9	.65	.09L
D209967	31.7	51	16	4.6	1.83	2.97	.98	6.4	.94	.09L
D209968	22.6	43	17	6.3	2.32	4.05	1.1	6.4	.55	.09L

Table 3.--Major- and minor-oxide and trace element composition of the laboratory ash of 16 coal samples from the Fort Union Formation, Fort Peck Indian Reservation, Roosevelt County, Montana--Continued

USGS sample No.	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Cu (ppm)	Ga-S (ppm)	Ge-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)
D209953	1500	5000	5	1.0	105	30	N	17	380	15
D209954	1500	15000	7	1.0L	75	30	N	12	350	20
D209955	1000	2000	5	1.0	87	30	N	67	355	10
D209956	1000	10000	5	1.0L	109	50	N	63	345	7L
D209957	1000	1000	5	1.0	93	50	N	43	335	15
D209958	1500	1500	3	1.0	84	30	N	61	470	10
D209959	1000	1000	5	2.0	140	70	70	23	660	30
D209960	1500	3000	15	1.0	66	30	N	23	1220	20
D209961	1000	1000	5	2.0	114	50	N	54	505	10
D209962	700	700	10	1.0	71	50	20L	25	210	10
D209963	1500	2000	3L	1.0	55	30	N	56	1330	10
D209964	1000	300	10	2.0	106	150	20L	10L	215	50
D209965	1000	500	10	1.0L	43	100	N	65	335	15
D209966	500	500	3	1.0L	64	30	N	68	150	20
D209967	500	500	5	1.0L	66	70	N	88	140	10
D209968	500	700	3	1.0	106	30	N	87	185	15

Table 3.--Major- and minor-oxide and trace element composition of the laboratory ash of 16 coal samples from the Fort Union Formation, Fort Peck Indian Reservation, Roosevelt County, Montana--Continued

USGS sample No.	Nb-S (ppm)	Ni-S (ppm)	Pb (ppm)	Sc-S (ppm)	Sr-S (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)
D209953	20L	20	36	20	5000	150	70	7	193	200
D209954	20L	30	25L	30	5000	150	50	5	170	150
D209955	20L	50	50	10	1500	200	50	5	196	300
D209956	20L	30	64	30	2000	200	50	5	152	500
D209957	20L	30	31	20	2000	200	50	5	296	200
D209958	20L	10	35	15	3000	100	50	3	164	150
D209959	20L	150	30	30	3000	500	70	7	173	500
D209960	20	70	25	30	7000	150	150	15	296	300
D209961	20L	15	36	20	3000	150	70	5	344	300
D209962	20L	30	25L	20	1000	150	100	10	118	300
D209963	20L	20	25L	15	2000	100	50	3	44	200
D209964	20L	300	47	50	1000	500	150	15	354	500
D209965	20L	50	28	15	1500	150	70	5	85	300
D209966	20L	30	52	10	1000	150	50	5	85	300
D209967	20L	50	47	20	1500	200	50	7	66	300
D209968	N	50	28	15	1500	200	50	3	72	150

Table 4.--Content of nine trace elements in 16 coal samples from the Fort Union Formation, Fort Peck Indian Reservation, Roosevelt County, Montana

[Analyses in air-dried (32°C) coal. L, less than the value shown. All analyses by U.S. Geological Survey laboratories, Lakewood, Colorado]

USGS sample No.	As (ppm)	Co (ppm)	Cr (ppm)	F (ppm)	Hg (ppm)	Sb (ppm)	Se (ppm)	Th (ppm)	U (ppm)
D209953	7.4	0.6	0.1L	20	0.20	0.4	0.8	1.9	1.4
D209954	4.8	.6	1.3	25	.16	.6	1.1	1.1	.7
D209955	6.9	1.4	4.6	65	.11	.8	1.4	3.0	2.5
D209956	1.7	1.0	5.4	50	.05	.6	1.5	3.6	2.5
D209957	32	1.2	.1L	65	.32	.7	.6	1.9	1.7
D209958	1.7	.4	2.8	20	.05	.6	.6	1.5	1.1
D209959	4.8	4.3	7.7	35	.11	1.6	.5	1.2	1.7
D209960	1.4	1.5	2.7	20L	.13	.3	.3	1.0	2.1
D209961	1.2	.6	4.2	40	.08	.5	.6	2.2	1.1
D209962	10	1.9	7.8	45	.19	1.7	.8	2.8	2.9
D209963	2.0	.5	2.7	25	.12	.3	.6	1.6	.9
D209964	564	13	.1L	50	.07	5.6	1.3	1.4	7.3
D209965	1.7	1.5	3.7	25	.08	.5	1.1	2.4	1.6
D209966	5.6	1.6	10	75	.09	1.4	2.3	6.1	5.0
D209967	24	2.0	18	120	.12	1.2	2.3	6.2	6.6
D209968	16	1.6	14	95	.32	1.9	2.3	3.7	4.4

Table 5.--Major-, minor-, and trace-element composition of 16 coal samples from the Fort Union Formation, Fort Peck Indian Reservation, Roosevelt County, Montana

[Values in percent or parts per million. As, Co, Cr, F, Hg, Sb, Se, Th, and U values are from direct determinations on air-dried (32°C) coal; all other values are calculated from analyses of coal ash. S after element title indicates analysis by emission spectrography; L, less than value shown; N, not detected. All analyses by U.S. Geological Survey laboratories, Lakewood, Colorado]

USGS sample No.	Si (percent)	Al (percent)	Ca (percent)	Mg (percent)	Na (percent)	K (percent)	Fe (percent)	Ti (percent)	As (ppm)	B-S (ppm)
D209953	0.80	0.57	1.1	0.28	0.74	0.022	0.75	0.017	7.4	150
D209954	.53	.37	.94	.23	.65	.020	.92	.013	4.8	150
D209955	2.9	1.6	.97	.24	.64	.15	.57	.043	6.9	150
D209956	3.0	1.7	1.1	.25	.69	.16	.29	.072	1.6	150
D209957	.90	1.2	1.2	.50	.052	.14	.51	.049	32	150
D209958	1.2	.76	1.3	.49	.045	.049	.27	.031	1.7	150
D209959	1.4	.74	1.0	.29	.51	.099	.69	.034	4.8	100
D209960	.52	.47	1.2	.28	.47	.022	.36	.019	1.4	100
D209961	1.7	.98	1.1	.32	.63	.075	.34	.038	1.2	100
D209962	2.3	1.1	1.2	.47	.097	.15	1.4	.042	10	100
D209963	1.2	.80	1.3	.82	.061	.045	.32	.033	2.0	150
D209964	1.5	.61	.81	.36	.062	.14	3.2	.035	564	150
D209965	1.7	1.3	1.2	.43	.057	.094	.25	.042	1.7	100
D209966	6.6	3.1	1.2	.47	.14	.41	.56	.011	5.6	150
D209967	7.6	2.7	1.0	.35	.70	.26	1.4	.18	24	150
D209968	4.5	2.0	1.0	.32	.68	.21	1.0	.074	16	100

Table 5.--Major-, minor-, and trace-element composition of 16 samples of coal from the Fort Union Formation, Fort Peck Indian Reservation, Roosevelt County, Montana--Continued

USGS sample No.	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Co (ppm)	Cr (ppm)	Cu (ppm)	F (ppm)	Ga-S (ppm)	Ge-S (ppm)	Hg (ppm)
D209953	500	0.5	0.11	0.6	0.1L	11	20	3	N	0.20
D209954	1500	.7	.09L	.6	1.3	7.1	25	3	N	.16
D209955	300	.7	.16	1.4	4.6	14	65	5	N	.11
D209956	1500	.7	.16L	1.0	5.4	17	50	7	N	.05
D209957	150	.7	.13	1.2	.1L	12	65	7	N	.32
D209958	150	.3	.09	.4	2.8	7.6	20	3	N	.05
D209959	100	.5	.22	4.3	7.7	15	35	7	7	.11
D209960	200	1.0	.07	1.5	2.7	4.9	20L	2	N	.13
D209961	100	.5	.22	.6	4.2	12	40	5	N	.08
D209962	150	1.5	.16	1.9	7.8	12	45	7	3L	.19
D209963	200	.3L	.10	.5	2.7	5.6	25	3	N	.12
D209964	50	1.5	.31	13	.1L	17	50	20	3L	.07
D209965	70	1.0	.11L	1.5	3.7	4.9	25	10	N	.08
D209966	150	.7	.27L	1.6	10	18	75	7	N	.09
D209967	150	1.5	.32L	2.0	18	21	120	20	N	.12
D209968	150	.7	.23	1.6	14	24	95	7	N	.32

Table 5.--Major-, minor-, and trace-element composition of 16 samples of coal from the Fort Union Formation, Fort Peck Indian Reservation, Roosevelt County, Montana--Continued

USGS sample No.	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Ni-S (ppm)	P (ppm)	Pb (ppm)	Sb (ppm)	Sc-S (ppm)	Se (ppm)
D209953	1.8	41	1.5	2L	2	43L	3.9	0.4	2.0	0.8
D209954	1.1	33	2	2L	3	38L	2.3L	.6	3	1.1
D209955	11	57	1.5	3L	7	64L	8.0	.8	1.5	1.4
D209956	9.8	54	1L	3L	5	62L	9.9	.6	5	1.5
D209957	5.5	43	2	2L	5	129	3.9	.7	2	.6
D209958	5.5	42	1	1.5L	1	72	3.2	.6	1.5	.6
D209959	2.5	71	3	2L	15	216	3.2	1.6	3	.5
D209960	1.7	90	1.5	1.5	5	222	1.8	.3	2	.3
D209961	5.9	55	1	2L	1.5	44L	3.9	.5	2	.6
D209962	4.0	34	1.5	3L	5	97	4.1L	1.7	3	.8
D209963	5.7	134	1	2L	2	444	2.5L	.3	1.5	.6
D209964	1.6L	34	7	3L	50	62L	7.3	5.6	7	1.3
D209965	7.4	38	1.5	2L	7	46L	3.2	.5	1.5	1.1
D209966	19	41	5	5L	7	110L	14	1.4	3	2.3
D209967	28	44	3	7L	15	127L	15	1.2	7	2.3
D209968	20	42	3	N	10	90L	6.3	1.9	3	2.3

Table 5.--Major-, minor-, and trace-element composition of 16 samples of coal from the Fort Union Formation, Fort Peck Indian Reservation, Roosevelt County, Montana--Continued

USGS sample No.	Sr-S (ppm)	Th (ppm)	U (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)
D209953	500	1.9	1.4	15	7	0.7	21	20
D209954	500	1.1	.7	15	5	.5	16	15
D209955	200	3.0	2.5	30	7	.7	31	50
D209956	300	3.6	2.5	30	7	.7	24	70
D209957	200	1.9	1.7	20	7	.7	38	20
D209958	300	1.5	1.1	10	5	.3	15	15
D209959	300	1.2	1.7	50	7	.7	19	50
D209960	500	1.0	2.1	10	10	1	22	20
D209961	300	2.2	1.1	15	7	.5	37	30
D209962	150	2.8	2.9	20	15	1.5	19	50
D209963	200	1.6	.9	10	5	.3	4.4	20
D209964	150	1.4	7.3	70	20	2	55	70
D209965	150	2.4	1.6	15	7	.7	9.7	30
D209966	300	6.1	5.0	50	15	1.5	23	70
D209967	500	6.2	6.6	70	15	2	21	100
D209968	300	3.7	4.4	50	10	.7	16	30

Table 6.--Elements looked for but not detected in 16 coal samples from the Fort Union Formation, Fort Peck Indian Reservation, Roosevelt County, Montana

[Approximate lower detection limits for these elements in coal ash, determined by the six-step spectrographic method of the U.S. Geological Survey are included]

Element	Symbol	Lower limit of detection (ppm) in coal ash
Silver	Ag	1
Gold	Au	50
Bismuth	Bi	20
Cerium	Ce	500
Dysprosium	Dy	100
Erbium	Er	100
Europium	Eu	200
Gadolinium	Gd	100
Hafnium	Hf	200
Holmium	Ho	50
Indium	In	20
Lanthanum	La	100
Lutetium	Lu	70
Neodymium	Nd	150
Palladium	Pd	5
Praseodymium	Pr	200
Platinum	Pt	100
Rhenium	Re	100
Samarium	Sm	200
Tin	Sn	20
Tantalum	Ta	1,000
Terbium	Tb	700
Tellurium	Te	5,000
Thallium	Tl	100
Thulium	Tm	50
Tungsten	W	200

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